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New York State Education Department

New York State Museum

61st ANNUAL REPORT

1907

In 3 volumes

VOLUME 3

APPENDIX 4

TRANSMITTED TO THE LEGISLATURE JANUARY 30, 1908

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1908

STATE OF NEW YORK

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STATE OF NEW YORK

No. 31

IN ASSEMBLY

January 30, 1908

61st ANNUAL REPORT

OF THE

NEW YORK STATE MUSEUM

VOLUME 3

To the Legislature of the State of New York

We have the honor to submit herewith, pursuant to law, as the 61st Annual Report of the New York State Museum, the report of the Director, including the reports of the State Geologist and State Paleontologist, and the reports of the State Entomologist and the State Botanist, with appendixes.

St Clair McKelway
Vice Chancellor of the University

Andrew S. Draper
Commissioner of Education

Appendix 4

Museum memoir 11

11 Graptolites of New York, part 2

New York State Education Department

New York State Museum

JOHN M. CLARKE, Director

Memoir 11

GRAPTOLITES OF NEW YORK

Part 2

GRAPTOLITES OF THE HIGHER BEDS

BY

RUDOLPH RUEDEMANN

ALBANY
NEW YORK STATE EDUCATION DEPARTMENT
1908

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New York State Education Department
Science Division, June 26, 1907

Hon. A. S. Draper LL.D.
Commissioner of Education

Dear sir: I communicate herewith for publication as a memoir of the State Museum, the manuscript and accompanying plates of part 2, *Graptolites of New York* prepared by Dr R. Ruedemann, Assistant State Paleontologist.

Part 1 of this work was published in 1905 and has met a most appreciative reception amongst the paleontologists of the world. The present contribution concludes the investigations which have been under way for a period of several years.

Very respectfully
John M. Clarke
Director

State of New York
Education Department
commissioner's room
Approved for publication this 28th day of June 1907

A. S. Draper
Commissioner of Education

PREFACE

The first instalment of the graptolites of New York was published as Memoir 7, New York State Museum. It comprises a résumé of the present status of our knowledge of graptolites and descriptions of the graptolites of the Upper Cambric and Lower Champlainic (Lower Ordovicic). The present volume contains the remainder of the graptolites, i. e. those of the Middle and Upper Champlainic, the Siluric and Devonic.

The correlation of the New York graptolite beds with those of other parts of America made it necessary to institute comparisons with graptolites from other states and the occasion has been used to describe and figure the relatively small number of forms from other parts of the country as far as these have been made accessible to us through the kindness of colleagues. The rich faunas of Canada have been excluded since we are informed that Professor Lapworth, the leader among modern investigators in this field, has been studying them for more than a decade.

During the prosecution of this investigation, the desirability of some introductory chapters to the second part of the treatise has urged itself upon the writer. These are wholly supplementary to those of the first part and contain bibliographic references, and morphologic and phylogenetic observations regarding the later graptolites here described. Some observations have been incorporated in the introduction because they could be dealt with more advantageously here than when scattered through generic and specific descriptions. The discussion of the range of the forms and the geographic distribution of the zones of the higher graptolite beds had for obvious reasons also to be reserved for this volume. A more complete correlation table of the zones incorporating those of the first volume is added; and also a synoptic table of the range of the genera of the higher beds. Finally, we have in completion of our work inserted a synoptic and synonymic list of the graptolites known from North America. A few notes on forms which at times have been considered as graptolites have been added in an appendix.

During this investigation of the higher graptolite faunas it has been found necessary to ask from the Director of the United States Geological Survey the loan of the types of a number of new species, mostly from the Normanskill shales of New York (Stockport, Columbia co., N. Y.), which had been described, but not figured, by Dr R. R. Gurley in the *Journal of Geology* [v. 4, 1896]. Our request was most liberally granted by the authorities of the United States Geological Survey and of the National Museum, but with the specimens there was delivered to us the voluminous unfinished manuscript of Gurley's monograph of the graptolites with the understanding that we should use as much as possible of the same, and thus assure to Dr Gurley's long labors, the credit to which they are entitled. The author has gladly availed himself of Gurley's work, which even in its fragmentary form bears witness not only of the admirable patience and enthusiasm of its author, but also of his keen power of observation.

In justice to both Dr Gurley and myself a full statement of what this voluminous manuscript contains and what has been used for this memoir, should be given in this place.

The greater part of the manuscript consists of copies of the descriptions, and translations of those in other than the English language, of all foreign species of graptolites together with a full bibliography of all species described up to 1896. It is obvious that it was the author's intention to produce a monograph of all the graptolites of the world.

Another part of the manuscript contains the history and synonymy of the American species. In this work Dr Gurley had evidently made special efforts to trace the history of many of the cryptic names of the earlier geologists, as those of the graptolites mentioned in the reports of the first geological survey of New York by Emmons and others. These notes are fairly complete; they have been used here as far as the scope of our work allowed and due credit given the author.

In the description of the North American graptolites Gurley had not proceeded beyond the Dendroidea and a part of the Graptoloidea of the Lower Champlainic. The former consist in the large majority of the

Niagaran forms from Hamilton, Canada, which lie without our field, and the descriptions of the latter faunas are entirely based upon Canadian material. Moreover, the Graptoloidea of the Lower Champlainic have already been described in Memoir 7 as far as they are found within the boundaries of the State. Of this part of the manuscript there could, for these reasons, be used only the descriptions of a few new Dendroidea from the Niagaran and the Devonic of New York. In case Professor Lapworth should not have extended his work to the remarkable Dendroid fauna of Hamilton, first made known by Spencer, this part of Gurley's work could easily be made complete by the addition of the descriptions of the few western forms and would become a valuable contribution to paleontology. The drawings of a considerable portion of the Dendroidea are finished; they are pen drawings made on blue prints from photographs, and very correct and effective. A few of them representing the New York species have been used in this publication, supplemented by camera enlargements.

The manuscript is accompanied by a considerable number of pen drawings of graptolites other than Dendroidea. These, being free-hand drawings made by a draftsman, are mostly diagrammatic though carefully executed. We have inserted them in the case of Gurley's new species in the text as his original drawings and supplemented them by camera enlargements and tracings from the types as far as the latter could be found.

A very valuable addition to the material sent from Washington is a manuscript report by Professor Lapworth on a collection of Stockport, N. Y. graptolites sent to him by Dr Gurley. It contains the descriptions of the new Normanskill species published in 1896 in the *Journal of Geology*. We have taken the liberty of incorporating Lapworth's important notes on Diplograptus foliaceus in our paper.

On the whole, it may be fairly said that Dr Gurley has printed in his preliminary publication in the *Journal of Geology* all that was new or especially worthy of publication, namely the descriptions of all new species — with the exception of a few Dendroidea — and his observations on the morphology of certain hitherto incompletely known species (e. g. Clath-

rograptus geinitzianus). Still, there was enough left in the manuscript to make it a welcome help to the writer in many ways. Its extensive bibliography of the graptolites, which is practically complete to 1896, might be published as a separate bulletin, as also eventually the Dendroidea. This done, full justice, I believe, would have been rendered to Dr Gurley's assiduous labors on the graptolites.

For the loan of collections and for valuable information I am sincerely thankful to Director Charles D. Walcott, Dr T. W. Stanton, Dr E. O. Ulrich, Mr Ray S. Bassler of Washington, to Prof. T. W. Sardeson of Minneapolis, Prof. Charles Schuchert of New Haven, Mr John Schuler of Rochester, Mr Edwin Kirk and Prof. R. P. Whitfield of New York.

April 1, 1907

Rudolf Ruedemann
Assistant State Paleontologist

GRAPTOLITES OF THE HIGHER BEDS

RANGE AND GEOGRAPHIC DISTRIBUTION

In part 1 of the *Graptolites of New York* we have drawn the division line between the Lower and Upper Graptolite faunas of New York above the third Deepkill zone (zone with Diplograptus dentatus). The reasons for this proceeding were partly of a practical and partly of a theoretical nature; on one hand we thus obtained an approximately equal division into halves of the subject-matter, and on the other since that zone had been roughly correlated with the Chazy formation, we left all the zones of the Canadian or Paleochamplainic period (the first of the three periods of the Champlainic) in association as they are usually found in the field. But we have already emphasized the fact that while the genera of the Axonolipa, which are characteristic of the Lower Graptolite fauna, viz, Dichograptus, Loganograptus, Tetragraptus and Phyllograptus, become extinct with this third zone, the Axonophora, which are characteristic of the Upper Graptolite fauna, appear abruptly in it with their important genera Diplograptus, Glossograptus and Climacograptus. The third Deepkill zone is hence truly transitional between the Lower and Upper Graptolite faunas, and if the now prevailing principle, that the division lines should be determined rather by the arrival of new forms than by the extinction of old ones, had been followed, this zone would have been joined to the Upper Graptolite fauna. It partakes, however, in this regard fully of the nature of its correlative, the Chazy formation, which also is more characterized by the advent of genera typical of the later Mohawkian, specially of the Trenton limestone, than by the extinction in it of the older genera of the Canadian era; and as long as the latter is united into one period with the preceding Beekmantown limestone by the New York geologists we are justified in conforming in regard to the corresponding graptolite zone.

Gurley [1896, p.304] has provisionally correlated certain small faunas from Mystic (Canada), Kicking Horse Pass (Canadian Rocky mountains) and Dease river (British Columbia) with the Chazy limestone, but since

these, as far as known, contain only species of the Normanskill fauna (Lower Dicellograptus zone) which is now known by direct stratigraphic evidence [*see* p.11] to be of Trenton age, they would, as prenuncial faunas of the Trenton, seem to be more properly correlated with the Lowville and Black River limestones.

Probably also the occurrence of Diplograptus foliaceus and Climacograptus scharenbergi in black limestone pebbles of the Rysedorph hill conglomerate [Ruedemann, 1901, p.92] in association with a rich brachiopod and trilobite fauna, including Bronteus lunatus, Calymmene senaria, Ceraurus pleurexanthemus and Sphaerocoryphe major, is indicative of a horizon intercalated between the third Deepkill zone and the Normanskill zone; for, although the writer in the paper before cited correlated this fauna of the black pebbles tentatively with the lower Trenton, a remoter (probably Black River) age has been claimed for it by some, apparently on good ground.

1 Normanskill shale (Zone of Nemagraptus gracilis or Dicellograptus zone)

The first zone of the Upper Graptolite fauna fully developed in this State is that of the Normanskill shale. The most important forms of its rich fauna were originally discovered in a cliff on the bank of the Normanskill, a small tributary of the Hudson emptying below Albany, and already described and beautifully illustrated in the first volume of the *Palaeontology of New York*. Further species, which were obtained when a railroad was built along this cliff, were described in a supplement to volume 3 of the same publication. The fauna was regarded by Hall as characterizing the "Hudson River shales" above the horizon of the Utica shale, a position which it held almost undisputed until 20 years ago when Lapworth, who had studied the same fauna from the Lower Canadian rocks, identified the zone with the British one of Coenograptus gracilis and since the latter corresponds to a part of the Llandeilo, inferred a younger (approximately Black River-Trenton) age for the Normanskill zone.[1] The writer

[1] A full account of the history of this zone has been given by the writer in N. Y. State Mus. Bul. 42.

SYSTEM	
Siluric	Clinton b
Champlainic	Richmon
	Lorraine
	Frankfort
	Utica sha
	Upper Tr Middle T Lower Tr Black Ri and Lo stone
	Chazy lim
	Beekmant stone
Cambric[2]	Schaghtic

[1] This in part replaces t

[2] It is still a mooted que

CORRELATION TABLE OF THE GRAPTOLITE ZONES OF NEW YORK[1]

SYSTEM	STAGE	GRAPTOLITE ZONES IN NEW YORK	DISTRIBUTION IN NORTH AMERICA	CORRESPONDING ZONES IN GREAT BRITAIN AND SCANDINAVIA	EXTRA-AMERICAN DISTRIBUTION
Siluric	Clinton beds	Z. of Monogr. clintonensis and Retiol. geinitzianus var. venosus	....	Z. of Cyrtog. murchisoni	Great Britain, France, Belgium, Scandinavia, Bohemia
Champlainic	Richmond beds?	....	Z. of Dicellog. complanatus in Indian Territory	Z. of Dicellog. complanatus	Great Britain, Scandinavia
	Lorraine beds	Z. of Diplog. peosta and D. foliaceus mut. vespertinus	Wisconsin, Minnesota	....	....
	Frankfort shale	Z. of Glossog. quadrimucronatus mut. posterus	Ohio, Canada	....	....
	Utica shale	Z. of Glossog. quadrimucronatus and Climacog. typicalis	Canada, Vermont, Pennsylvania, Ohio, Wisconsin and Minn. (Maquoketa shale and part of Galena?)	Z. of Pleurog. linearis	Great Britain, Scandinavia
		Subzone of Climacog. caudatus and Corynoides curtus mut. comma	....	....	....
	Upper Trenton Middle Trenton	Z. of Diplog. amplexicaulis (Upper Dicellograptus zone)	Canada (Magog, Cove Fields, etc.)	Z. of Dicranog. clingani	Great Britain, Scandinavia
	Lower Trenton Black River limestone and Lowville limestone	Z. of Nemag. gracilis (Normanskill shale)	Canada, New Jersey, Alabama, Arkansas, Indian Territory, Nevada, British Columbia	Z. of Nemag. gracilis	Great Britain, Scandinavia, France? New South Wales and Victoria
	Chazy limestone	Z. of Diplog. dentatus and Cryptog. antennarius (Third Deep kill zone)	Canada (Point Levis zone), Arkansas, Nevada	Z. of Didymog. geminus	Great Britain, Scandinavia
		Subzone (transitional zone) with Did. forcipiformis (Ash hill quarry)	....	....	....
	Beekmantown limestone	Z. of Didymog. bifidus and Phyllog. anna	Canada (St Anne zone), Newfoundland	Z. of Didymog. bifidus and Phyllog. typus (Upper Tetrag. zone)	Great Britain, Scandinavia, France, Bohemia, Victoria
		Z. of Tetragraptus subz. b of Goniog. subz. a of Clonog.	Canada (Main Point Levis zone)	Z. of Tetragraptus (Lower Tetrag. and Dichog. zones)	Great Britain, Scandinavia, France, Victoria
Cambric[2]	Schaghticoke shale	Z. of Dictyonema flabelliforme	Canada (Gaspé, St John)	Z. of Dictyonema flabelliforme	Great Britain, Scandinavia, Esthonia, Belgium

[1] This in part replaces the correlation table in Memoir 7 [facing p. 490].

[2] It is still a mooted question whether the shale of Dictyonema flabelliforme constitutes the last horizon of the Cambric or the first of the Champlainic (Lower Siluric) and several authors have lately inclined to the latter view.

showed in 1901 that the belt of slate which contains this fauna in the Hudson river region underlies the Utica shale and correlated the zone with the lower or middle Trenton.

Since then still more direct evidence for the Trenton age of the Normanskill Graptolite fauna has come to light. Weller [1903, p.52] has found the fauna in New Jersey near the base of the shale formation, from 50 to 75 feet above the Parastrophia hemiplicata zone which is near the base of the Trenton limestone; and, since the sequence from the Trenton limestone to the "Hudson River slates" at the locality is normal for New Jersey, concluded that the graptolite beds "would seem to be equivalent to about the middle portion of the typical Trenton limestone of New York, or even to a position below the middle."

Through the liberality of Prof. Eugene A. Smith, State Geologist of Alabama, the writer has had the privilege of studying a well preserved, slightly modified Normanskill fauna occurring in calcareous shale in Bibb county, Alabama, which is associated with Trenton limestone and according to Professor Smith of upper Trenton age. The following section of this interesting locality has been kindly furnished.

Section at Pratt's Ferry, Bibb county, Alabama, in descending order:

1	Black shales, weathering yellowish and forming light yellow soil. Thickness not given	FEET
2	Bluff of bedded chert	10–15
	Talus or slope of 40 feet vertical hight	
3	Heavy bedded chert	15–20
4	Sandstone	15
5	Beds of chert with Subcarboniferous fossils	20
6	Sandstones alternating with black slates, but mostly sandstone	60
7	Strata not seen	20
8	Calcareous shales with graptolites, bluish black but weathering gray or white breaking up into small shaly blocks	40
9	Thin bed of chert. Thickness not given	
10	Gray calcareous shales like no. 8, graptolitic	100
11	A thin bed of sparry limestone full of small fossils and also graptolites (?). Thickness not given	

		FEET
12	Calcareous shales full of graptolites	50
13	Sandy reddish shales breaking up into square-faced pieces	10

Below these fossiliferous limestones there are 600 to 800 feet of massive limestones and marble with Orthoceras. These include the Chazy (with Maclurea magna) and Trenton. The graptolite beds are, as the section shows, at the top of the series, not far below chert beds with Subcarboniferous fossils.

The fauna consists of the following species:

Nemagraptus gracilis *var.* surcularis *Hall* (r)
Dicellograptus smithi *nov.* (cc)
D. moffatensis *Carruthers var.* alabamensis *nov.* (cc)
D. cf. mensurans *nov.* (rr)
Diplograptus foliaceus *var.* alabamensis *nov.* (cc)
Climacograptus cf. putillus (*Hall*) (c)
Cryptograptus tricornis (*Carruthers*) (c)
Glossograptus ciliatus *Emmons* (c)

While the essential identity of this fauna with our Normanskill graptolite fauna can not be gainsaid, this identity can not be taken as demonstrating more than the general fact of the Trenton age of the Normanskill fauna, because, on one hand, the Alabama fauna contains enough differing elements to be not exactly identical and on the other hand it is open to question whether this upper Trenton of Alabama is exactly equivalent to ours.

Hence while the Trenton age of the Normanskill zone can be considered as well established, its exact place in the Trenton formation is still open to question. On the other hand, the position of the Normanskill fauna in New Jersey and Alabama excludes also the possibility that that fauna can be of greater than Trenton age; hence it can not be placed between the Chazy and Trenton limestone as Lapworth provisionally assigned it. The fact that still another well differentiated zone [see *postea* p.29] intervenes between those of the Normanskill and Utica shales and the marked difference of the Normanskill and Utica faunas argue strongly however for the position of the Normanskill shale below the upper Trenton.

Since the original discovery of the zone at the Normanskill, numerous other localities, to be noted further on, have become known in the slate belt of eastern New York on both sides of the Hudson river. Walcott, in his investigation of the slate belt [1888] discovered many localities, espe-

cially in Washington and Rensselaer counties, and Dale and Prindle in their continuation of these studies have added considerably to the list of localities. During the construction of the West Shore Railroad Hall secured for the State Museum a very large collection of splendidly preserved graptolites — in fact the best preserved Normanskill graptolites known to the writer — from a cut near Glenmont station in Albany county, and the writer has obtained large collections from Mount Moreno near Hudson, Columbia county, and other localities, while Gurley has based his investigation of the fauna on a large collection secured by him at Stockport, also in Columbia county, N. Y. All these occurrences have demonstrated that the Normanskill fauna is probably not only present in a large area of the slate belt of New York, but is also by far the most commonly met with of the graptolite faunas of the shales and slates of eastern New York, while it is absent outside of the area of the former Appalachian basin, or from the central and northwestern part of the State where the shale is replaced by the Trenton limestone.

The complete fauna, as known in this State, is given in the following table which shows its distribution in the four principal localities.

TABLE 1 GRAPTOLITES OF THE NORMANSKILL SHALE IN NEW YORK

	Normanskill (Kenwood)	Glenmont	Mt Moreno	Stockport	Other localities in New York
1 Ptilograptus poctai *nov*	....	x	....	....	none
2 Dictyonema spiniferum *nov*	....	x	....	....	none
3 Odontocaulis hepaticus *nov*	....	x	....	....	none
4 Desmograptus tenuiramosus *nov*	....	x	....	....	none
5 Thamnograptus capillaris (*Emmons*)	x	x	x	x	
6 *Cf.* Protovirgularia dichotoma *McCoy*	....	....	....	x	none
7 Didymograptus sagitticaulis (*Hall*) *Gurley*	x	....	x	x	Moordener kill
8 D. serratulus (*Hall*)	x	....	....	x	Lansingburg
9 D. subtenuis (*Hall*)	x	....	x	x	
10 Azygograptus walcotti *Lapworth*	....	....	....	x	none
11 A. ? simplex *nov*	....	x	x	....	Lansingburg

TABLE I GRAPTOLITES OF THE NORMANSKILL SHALE IN NEW YORK (*continued*)

	NORMANSKILL (KENWOOD)	GLENMONT	MT MORENO	STOCKPORT	OTHER LOCALITIES IN NEW YORK
12 Leptograptus flaccidus *mut.* trentonensis *nov.*	....	x	x	....	none
13 *id. var.* spinifer *mut.* trentonensis *nov.*	....	x	....	....	none
14 *id. var.* spinifer *mut.* trifidus *nov*	....	....	x	....	none
15 Syndyograptus pecten *nov*	....	x	....	....	none
16 Amphigraptus divergens (*Hall*)	x	x	....	....	none
17 A. multifasciatus (*Hall*)	x	....	....	....	none
18 Nemagraptus gracilis (*Hall*)	x	x	x	x	many
19 *id. var.* surcularis *Hall*	x	x	....	x	Granville
20 *id. var.* crassicaulis *Gurley*	....	....	....	x	none
21 *id. var.* distans *nov*	....	x	....	....	none
22 *id. var.* approximatus *nov*	x	x	....	....	none
23 N. exilis *Lapworth*	....	x	....	x	Granville
24 *id. var.* linearis *nov.*	x	x	x	x	Speigletown
25 Dicellograptus mensurans *nov.*	x	....	....	....	none
26 D. divaricatus (*Hall*)	x	x	....	x	Granville
27 *id. var.* rectus *nov*	x	....	....	....	Speigletown
28 *id. var.* bicurvatus *nov.*	x	x	....	....	none
29 *id. var.* salopiensis *Elles & Wood*	x	....	....	x	none
30 D. intortus *Lapworth*	....	....	....	x	Speigletown
31 D. gurleyi *Lapworth*	...	x	x	x	Granville
32 D. sextans (*Hall*)	x	x	x	x	many
33 *id. var.* exilis *Elles & Wood*	....	x	x		
34 *id. var.* perexilis *nov.*	....	....	x		
35 *id. var.* tortus *nov*	x	....	....	....	none
36 Dicranograptus nicholsoni *var.* parvangulus *Gurley*	....	x	x	x	
37 *id. var.* diapason *Gurley*	....	x	....	x	Granville
38 D. ramosus *Hall*	x	x	x	x	many
39 D. spinifer *Elles & Wood*	....	x	x		
40 *id. var.* geniculatus *nov*	....	x	x	....	none
41 D. furcatus *Hall*	x	x	....	x	Granville, Greenwich, Wash. co.
42 *id. var.* exilis *nov*	x	....	....	....	none
43 D. contortus *nov*	x	....	....	....	none
44 Corynoides calicularis *Nicholson*	....	x	....	x	
45 C. gracilis *mut.* perungulatus *nov*	....	x	x	....	Speigletown
46 Diplograptus foliaceus *Murchison*					
47 *id. var.* incisus *Lapworth*	....	x	x	x	many
48 *id. var.* acutus *Lapworth*	x	x	x	x	many
49 D. angustifolius *Hall*	x	x	x	x	many
50 D. euglyphus *Lapworth*	....	x	x	....	Speigletown
51 *id. var.* pygmaeus *nov.*	....	....	....	....	Lansingburg
52 Glossograptus ciliatus *Emmons*	x	x	x	x	

TABLE 1 GRAPTOLITES OF THE NORMANSKILL SHALE IN NEW YORK (*concluded*)

	NORMANSKILL (KENWOOD)	GLENMONT	MT MORENO	STOCKPORT	OTHER LOCALITIES IN NEW YORK
53 *id. var.* debilis *nov*	....	....	x	....	none
54 G. whitfieldi (*Hall*)	x	x	x	x	
55 Cryptograptus tricornis (*Carruthers*)	x	x	x	....	many
56 Climacograptus parvus *Hall*	x	x	....	x	many
57 C. putillus *mut.* eximius *nov*	....	x	....	....	Lansingburg
58 C. modestus *nov*	....	....	x	....	Lansingburg
59 C. scharenbergi *Lapworth*	....	x	x		
60 C. bicornis *Hall*	x	x	x	x	many
61 Retiograptus geinitzianus (*Hall*)	x	....	....	x	Chatham,
62 Lasiograptus mucronatus (*Hall*)	x	x	x	x	Schodack land'g
63 L. bimucronatus *Nicholson*	x	x	x	....	Moordener kill

This wonderfully rich fauna, consisting of some 60 species of graptolites, is, however, in the great majority of the outcrops only preserved in a very fragmentary condition, i. e. in but a few of the most common and characteristic forms. Only the four localities given in the foregoing list, viz, Normanskill (Kenwood), Glenmont near Albany, Mt Moreno near Hudson, and Stockport in Columbia county have furnished complete or nearly complete faunas. Of these, Glenmont has yielded the most complete series, 41 forms, Mt Moreno 32, Stockport 30 and Normanskill 29. The faunas of all these four localities can be considered as typically representing the Normanskill association and as being strictly of one horizon. The slight differences in their associations are probably largely referable to the greater or less completeness of the collections. A few notable differences, not so readily explained, are the occurrence of the Dendroidea in the Glenmont collection alone (with the exception of Thamnograptus capillaris) and the scarcity of the Didymograpti in the same collection, while the latter prevail in the shales of Mt Moreno.

The following is a list of smaller faunules (or collections) of this horizon, obtained in this State:

TABLE 2

	Schodack Landing, Columbia Co.	Moordener Kill, near Castleton	Mount Olympus, Troy	Poesten Kill, Troy	Lake Aries, Rensselaer Co.	Pittston Corners, Rensselaer Co.	McDougal's Lake, Washington Co.	North of Battenville, Washington Co.	¾ m. S. S. E. of Hebron, Washington Co.	2½ m. N. of Middle Granville, Washington Co.	1 m. N. of N. Granville, Washington Co.	S. E. corner of Granville, Washington Co.
Thamnograptus capillaris (*Emmons*)	x											
Didymograptus sagitticaulis *Gurley*	x	x	....	...	x	....	....	x	x			
D. subtenuis (*Hall*)	x	....	x	x								
D. serratulus (*Hall*)	x	....	....	....	....	....	....	x				
Nemagraptus gracilis (*Hall*)	x	....	....	....	....	....	x	....	x	....	x	
id. var. surcularis (*Hall*)	....	....	....	....	....	....	....	....	....	x		
id. var. crassicaulis *Gurley*	x											
N. exilis *Lapworth*	....	....	....	....	....	....	....	....	....	x	x	
Azygograptus ? simplex *nov*	....	....	x	x								
Dicellograptus sextans (*Hall*)	x	x	....	....	....	x	x	x	....	x		
D. divaricatus (*Hall*)	x	....	....	....	....	....	x	....	....	x		
D. gurleyi *Lapworth*	....	....	....	....	....	....	....	....	....	x		
Dicranograptus ramosus *Hall*	x	x	x	....	....	....	x	....	....	x	....	x
D. nicholsoni *var.* parvangulus *Gurley*	....	....	....	....	....	....	....	....	....	....	....	x
id. var. diapason *Gurley*	....	....	....	....	....	....	....	....	....	x		
D. contortus *nov*	....	....	x									
D. furcatus *Hall*	x	....	....	....	....	....	x	x	....	x	x	
Corynoides calicularis *Nicholson*	....	x	....	x								
Diplograptus foliaceus *Murchison*	x	x	....	x	x	....	x	....	x	x	x	x
D. euglyphus *Lapworth*	....	....	....	....	....	....	....	....	....	....	....	x
D. angustifolius *Hall*	....	x	...	....	(x)	x	....	....	....	x		
Cryptograptus tricornis (*Carr*)	x	....	....	x	x	....	....	x				
Climacograptus bicornis *Hall*	x	x	x	x	....	....	x	....	....	x	....	x
C. parvus *Hall*	x	x	x	x	x	x	....	....	....	x		
Lasiograptus mucronatus (*Hall*)	x	....	....	....	x	....	....	....	....	x		

As this list shows, none of the species appears in every collection, but a few species are mostly present. These are Nemagraptus gracilis, Dicellograptus sextans, D. furcatus, Diplograptus foliaceus, D. angustifolius, Climacograptus parvus and C. bicornis.

It is further to be noted that, while the association in general may be said to have been everywhere the same in these localities, still one form is frequently found profusely and as the most common of all in one locality, while in the others it is absent. Thus Dicranograptus furcatus is extremely common at the locality 1 mile north of Granville and near McDougal's lake, Climacograptus parvus at Pittston corners and Dicranograptus ramosus 2½ miles north of Middle Granville. To know whether these dominant species will ever become the means of a further subdivision of the zone lies at present beyond the scope of our facts, though in view of the considerable thickness of the rocks carrying the Normanskill fauna a future subdivision seems quite possible and is certainly much to be desired.

Nemagraptus gracilis has been considered the most characteristic form of the equivalent zone in Europe, and Lapworth has also termed this zone in Canada the "zone with Coenograptus gracilis." It is, however, possible, according to Ami's observation, that this species passes also into the next zone. Dicellograptus sextans, Dicranograptus furcatus and Climacograptus parvus are, of the more abundant forms, apparently most strictly bound to this zone and therefore among its best index fossils.

The genera, which pass but little below and above this horizon, and here distinctly reach their climax by the number of different forms, size and number of individuals, are Nemagraptus, Dicellograptus and Dicranograptus. The term Lower Dicellograptus subzone, proposed by Gurley [1892, p.403] is therefore quite appropriate with the limitation, that, since the next zone is markedly free from Dicellograpti the term Upper Dicellograptus zone is better replaced by another and the lower zone may be

simply termed the Dicellograptus zone. Altogether, the fact of the great difference in the faunal expressions of this and the following zone, in which the biserial forms entirely dominate and the distinct presence of faunules, which eventually may be recognized as subzones of the Dicellograptus zone, necessitate the recognition of the latter as a separate unit.

One of these subzones is quite obviously represented by a faunule collected by the writer at the power house of the traction company, north of Lansingburg. While having in common with the other outcrops of Normanskill shale the species: Didymograptus serratulus, Azygograptus ? simplex, Dicranograptus ramosus, Climacograptus parvus, C. modestus, C. bicornis and Diplograptus foliaceus, this faunule contains in Diplograptus amplexicaulis var. pertenuis, Diplograptus euglyphus var. pygmaeus, Climacograptus putillus mut. eximius and Corynoides gracilis, peculiar elements of its own. It is characterized by the great prevalence of minute Diplograpti and Climacograpti (C. modestus, C. parvus, C. putillus mut. eximius) and would seem to represent for this reason a transition to the next zone.

Another peculiar association has been observed by me near Speigletown, north of Troy. It consists of

Nemagraptus exilis *var.* linearis	Corynoides gracilis *mut.* perungulatus
Dicellograptus divaricatus *var.* rectus	Diplograptus euglyphus
D. intortus	

The localities mentioned in the foregoing tables are situated in the two belts of Champlainic rocks which with some interruptions flank the Lower Cambric slates of the slate belt of eastern New York. They lie in Columbia, Rensselaer and Washington counties or on the east side of the Hudson river, with the exception of those of Normanskill (Kenwood) and Glenmont, which are in Albany county and on the west side of the river. The zone itself has not yet been mapped, with the exception of a small area in the neighborhood of Albany in a former paper of the writer [1901] and its cartographic fixation will, no doubt, lead to a distinction of its subzones and of

their relative positions. In the broad belt of "Hudson River shales" extending south and southeast of Columbia county, into New Jersey, few localities have become known. One of these, consisting of the cuts of the West Shore Railroad near Highland, opposite Poughkeepsie, was made known by Booth in 1883. Among the graptolites identified by Whitfield from this outcrop are Nemagraptus gracilis, Didymograptus sagitticaulis, Dicranograptus furcatus and Cryptograptus tricornis. The museum of Columbia University also contains a small series of graptolites from Poughkeepsie indicating the presence of this horizon in Dutchess county.

In *New Jersey*, graptolites referable to the Dicellograptus zone have been found in two localities [Weller, 1903, p.52]. One of these has furnished:

Corynoides calicularis *Nicholson*
Diplograptus foliaceus (*Murchison*)
D. angustifolius (*Hall*)
Lasiograptus mucronatus (*Hall*)

the other:

Nemagraptus gracilis (*Hall*)
Dicranograptus ramosus *Hall*
Climacograptus parvus *Hall*
Retiograptus geinitzianus *Hall*

No outcrops of this zone in the Appalachian geosyncline south of those in New Jersey are positively known to the writer with the exception of that in *Alabama* found by Professor Smith. It is here, however, to be noted that the enigmatic species from Augusta county, Virginia, and Parrotsville, Tennessee, described by Emmons [American Geology, pt 2, p.106 ff] as Monograpsus elegans, Cladograpsus dissimilaris, C. inequalis and Diplograpsus ciliatus are more suggestive of the Normanskill zone than of any other, as already pointed out by Lapworth [1879, p.426] who recognizes Dicranograptus ramosus in one of the species of Cladograpsus. The "Monograpsus" is a Didymograptus and the Diplograpsus ciliatus a Glossograptus and probably identical with G. ciliatus [*see ibid.*].

Collections of graptolites from *Pennsylvania* and *Virginia* sent to the writer by Dr Ulrich for inspection did not contain any elements of the

Dicellograptus fauna. Of the Alabama graptolites [*see* list on p. 12] Nemagraptus gracilis var. surcularis, Dicellograptus cf. mensurans, Cryptograptus tricornis and Glossograptus ciliatus are forms occurring in our Normanskill shale; Cryptograptus tricornis also entering into the next zone. Dicellograptus smithi is a close relative of D. sextans, another Normanskill form, indicating a transition of that species to Dicranograptus. Likewise Dicellograptus moffatensis var. alabamensis and D. foliaceus var. alabamensis are provincial representatives of species occurring in this horizon but also found in later beds; the former is thus far known only from Great Britain, where it ranges from the Llanvirn to the Hartfell beds, the other is a cosmopolitan form. A small Climacograptus which is nearest related to C. putillus may indicate synchrony with one of the later subzones of the Dicellograptus beds, and the large percentage of forms closely related to, but still distinct from Normanskill species, is probably best explained as due to geographical or provincial separation.

Following the slate belt northward into and through *Vermont*, no outcrops of the Normanskill shales have as yet been found in that State, but the presence of the zone with identical faunas in *Canada* for a long distance along the St Lawrence, made known by Lapworth [1887, Griffin Cove, Marsouin river, Little Méchin river, Cape Rouge, Quebec, Fox and Magdalene rivers] and Ami [1889, Island of Orleans, Etchemin river, Quebec, and Montmorency river, Quebec, etc.] leave little doubt of the continuation of the zone through Vermont; and also the occurrence of an outcrop of the next graptolite zone near Lake Memphremagog, close to the Vermont and Canada boundary line points to the same inference.

The apparent absence of the Normanskill shale from Vermont is quite obviously due to the stronger folding of the slate belt, possibly under the influence of the Adirondack massive in the west. This finds its expression in the greater vertical hight of the resulting mountain chains (Green mountains) and has led to a narrowing of the belts of shales and their

stronger dynamic metamorphism; all of these factors tending to obscure the possible outcrops of the horizon.

The presence of Normanskill shale in northern *Maine* has been made known by Dodge [1890] and Ami has lately [1905] announced the occurrence in *New Brunswick* of a graptolite faunule that belongs to this or the following horizon.

West of the regions just mentioned the Dicellograptus fauna has not been observed again on this side of the Mississippi river. Its *distribution in eastern North America* may therefore be said to be *restricted entirely to the Appalachian geosyncline* and to some minor Atlantic embayments on the northeastern edge of the continent. In the Appalachian province again it is in the north strictly confined to the area which Ulrich and Schuchert [1902] have defined as the Levis channel, i. e. a narrow belt striking from New Jersey northward between the Quebec barrier and the Green mountain barrier to the St Lawrence, which it then follows to the St Lawrence gulf. The fauna entered this channel from the north and advanced, according to Ulrich and Schuchert, southward with the gradual submergence of the Appalachian valley trough, apparently never reaching beyond the present site of New Jersey. Its northeastern derivation is indicated by its northward connection with a sea which, as shown by the other embayments (Maine etc.), contained this fauna, by the European relations of the fauna to be noted further on and the apparent southward restriction of its area.

The provincial differentiation of the northern fauna from that of Alabama would also seem to argue for an interruption of the connection in the middle third of the Appalachian valley trough, the northern fauna occupying the Levis channel or the northern third and the Alabama fauna all or a portion of the Lenoir basin or southern third. Whether this supposed invasion of the Dicellograptus fauna into the northern third was preceded by a draining of the Levis channel at the close of the Chazy with a subsequent resubmergence as Ulrich and Schuchert suggest, or whether it resulted from a separation of the southern and northern basins by a gradual elevation of the middle third would seem open to question. We

had found [Mem. 7, p.503] in the Deepkill graptolite faunas an element which strongly urged a closer connection of the same with the homotaxial Australian faunas, and for this reason inferred an open marine connection of the Levis channel southward or westward with the Pacific ocean — besides occasional openings of the basin to the Atlantic by means of the Newfoundland embayment — a view which has meanwhile received further support by the recognition of the presence of Mississippian (and Pacific) elements in the cephalopod faunas of the equivalent limestone beds in the adjoining Chazy basin.

Since now the Upper Cambric Dictyonema shale, the rocks of the Deepkill horizons corresponding to the Beekmantown and those of the third zone, probably homotaxial with the Chazy, as well as the Dicellograptus zone, and, as shown further on also the succeeding zone, are coextensive in the Levis basin, the legitimate inference is that graptolitiferous beds were formed in that basin continuously from the Upper Cambric to late Trenton age with the exception of slight transgressions of the Mississippian sea in Trenton time, or in other words, that this basin,— or like physical conditions — existed continuously through all these ages, its waters remaining always in connection with the Newfoundland embayment and gaining occasionally access to the Mississippian sea and thereby to the Pacific ocean. I believe that when all graptolite horizons of the Levis basin with their subhorizons shall have been distinguished and their proper succession recognized, a practically uninterrupted series of graptolite beds will become known extending from the Upper Cambric to the Utica invasion.

An undubitable Dicellograptus fauna has been made known by Gurley from the novaculite region in *Arkansas* [1892, where it was referred to the next zone, and 1896] which also has furnished a Beekmantown graptolite fauna. Although the material is not favorably preserved, the following forms of our Normanskill beds can be clearly recognized :

Thamnograptus capillaris (*Emmons*)
Didymograptus sagitticaulis *Gurley*
Didymograptus serratulus *Hall*
Nemagraptus gracilis (*Hall*)

Dicellograptus divaricatus (*Hall*)
D. intortus *Lapworth*
Dicranograptus ramosus *Hall*
D. nicholsoni *var.* parvangulus *Gurley*
Corynoides gracilis *mut.* perungulatus[1] *nov.*
Diplograptus foliaceus *Murchison*
D. angustifolius *Hall*
Cryptograptus tricornis (*Carruthers*)
Climacograptus bicornis *Hall*
C. antiquus *Lapworth* ?
Glossograptus whitfieldi (*Hall*)
G. ciliatus *Emmons*
Lasiograptus mucronatus (*Hall*)
Leptobolus walcotti[2] *Ruedemann*

This association leaves no doubt of the homotaxy of the beds with the Dicellograptus zone of New York. But the black Arkansas shales also contain a few forms which by number and relative size are very prominent in the faunule and which do not occur in the Appalachian valley trough. These are:

Dicellograptus divaricatus *var.* rigidus *Lapworth*
Dicranograptus nicholsoni *var.* arkansasensis *Gurley*
Diplograptus foliaceus *var.* trifidus *Gurley*[3]

The most noteworthy feature of these three forms is that they are identical with British varieties while they have not yet been observed in either eastern America or Australia. Dicellograptus divaricatus var. rigidus is a Glenkiln form, first described by Lapworth. Dicr. nicholsoni var. arkansasensis is, as noted in the description of the form here given, quite probably identical with an undescribed British variety of Dicr. nicholsoni that is figured in the *Monograph of British Graptolites*, plate 25, figure 1g, though the Normanskill shale of New York has also furnished a similar form in D. spinifer var. geniculatus.

[1] Overlooked in the original listing of the Arkansas graptolites.

[2] Not listed by Gurley, but since described by the writer from the Normanskill shale of New York.

[3] Dr Gurley lists also from Arkansas: Dictyonema obovatum n. sp., Leptograptus cf. annectans and Dicellograptus elegans var. The first of these, based on a single type, I have been unable to find in the collection of the National Museum from Arkansas; the second identification refers to a very poorly preserved specimen and the third again has not been found. The last named species in England pertains to a higher horizon and its identification is doubtful [*see* Gurley 1896, p.296].

Diplograptus foliaceus var. trifidus is either identical with or but little different from D. foliaceus var. calcaratus Lapworth. This evidence is, of course, by no means sufficient to infer a closer connection of the Arkansas sea with the far-off British embayment of the North Atlantic, for it is to be noted that the forms mentioned are varieties of much varying and widely distributed species and may hence be convergent or parallel forms developed independently in different provinces; and further Dicellograptus divaricatus and Diplograptus foliaceus var. calcaratus do not appear in Great Britain until the Hartfell shale stage. If they are not parallel but identical varieties, the suggestion could be made that the western sea stood in connection with the northeastern embayments of the North Atlantic sea by means of the Arctic ocean and the Baltic sea, the latter of which has also furnished Diplograptus foliaceus var. calcaratus (in Scandinavia)[1], the forms having originated in the Pacific basin and reached the North Atlantic and Baltic basins later on.

From collections made by Ulrich in the shales associated with novaculite in the Talihina formation of the Ouachita mountains in *Indian Territory*, I infer that a horizon in close proximity to that of the Dicellograptus shale occurs there. One of the collections [loc. 240] contains:

Dicellograptus divaricatus *var.* bicurvatus *nov.*

Diplograptus foliaceus *Murchison*

D. foliaceus *var.* (closely related to D. crassitestus nov. and probably identical with D. trifidus Gurley)

Climacograptus *cf.* antiquus *Lapworth*

Another [loc. 240a] has furnished:

Dicellograptus divaricatus *var.* rigidus *Lapworth*

Dicranograptus ramosus *Hall*

Climacograptus bicornis *var.* tridentatus *Lapworth*

The occurrence of the variety of Dipl. foliaceus probably rep-

[1] See chart in part 1 of this monograph [Mem. 7, p.488] which will, with slight changes, also serve to illustrate the present discussion in view of the continuous deposition of graptolitiferous beds during Champlainic time in the same regions.

resenting trifidus, of C. cf. antiquus and of the variety rigidus of Dicell. divaricatus suggests the homotaxy and provincial unity of the Arkansas and Indian Territory beds.

Small faunules which contain elements of the Normanskill fauna have also been collected in *Nevada* by the geologists of the national government. One from the Silver Peak quadrangle contains:

Nemagraptus *sp.*	Diplograptus angustifolius *Hall*
Dicellograptus divaricatus *Hall*	D. *cf.* euglyphus *Lapworth*
Dicranograptus furcatus *Hall*	Climacograptus *sp.*

The specimens are much distorted.

Another from *Belmont*, *Nevada* [Wheeler Survey Rep't, 1875, v. 4, and Gurley, 1896, p.306] consists of Diplograptus foliaceus and Dicranograptus nicholsoni var. whitianus. The presence of the Normanskill zone or a closely preceding stage has long been known in the *Rocky mountains of Canada* and in *British Columbia.* Lapworth has recorded [1886] from *Kicking Horse* (Wapta) *Pass*, Rocky mountains:

Didymograptus *nov. aff.* D. euodus *Lapworth*	Cryptograptus tricornis *Carruthers*
Glossograptus ciliatus *Emmons*	Diplograptus angustifolius *Hall*
G. spinulosus *Hall*	D. rugosus *Emmons*
	Climacograptus caelatus *Lapworth*

and from the shales along *Dease river*, *British Columbia* [1889]:

Diplograptus euglyphus *Lapworth*	Glossograptus ciliatus *Emmons*
Climacograptus *cf.* antiquus *Lapworth*	Didymograptus *cf.* sagittarius (*Hall*)
Cryptograptus *cf.* tricornis (*Carruthers*)	New form allied to Nemagraptus[1]

[1] Lapworth suggests that both the Kicking Horse pass and Dease river faunas may be a little older than the Normanskill fauna, mainly on account of the absence of the Dicranograptidae, Leptograptidae and Nemagraptidae. Since in America also the so called Upper Dicellograptus zone and the succeeding Utica shale are markedly free of these groups, the possibility has to be taken into account that they may be slightly younger than the typical Normanskill aggregation. At any rate it would seem to be giving an exaggerated importance to this difference in faunal composition if they are correlated with the Chazy [Gurley, 1896, p.304], for it must be noted that practically all elements of these faunules are present in our Normanskill fauna and they therefore can not be far removed from early Trenton age.

While the localities of the Rocky mountain region demonstrate the presence of the Normanskill fauna in the easternmost part of the Pacific basin, *Australia* has also furnished ample evidence of the presence of this fauna in the southwestern part of the basin. T. S. Hall records the presence of the beds characterized by the Dicranograptidae from *New South Wales* [1902] and *Victoria* [1896, 1899].

From the former colony are cited:

Dicellograptus *cf.* divaricatus *J. Hall*
D. *cf.* elegans *Carruthers*
Dicranograptus zic-zac *var.* minimus *Lapworth*
Diplograptus foliaceus *Murchison*
D. *cf.* whitfieldi *J. Hall*
Climacograptus bicornis *J. Hall*
Glossograptus *cf.* mucronatus (*J. Hall*)
Clathrograptus *cf.* geinitzianus (*J. Hall*)

From Victoria we find cited by the same careful author:

Nemagraptus gracilis (*J. Hall*)
Dicranograptus ramosus (*J. Hall*)
D. nicholsoni *Hopkinson*
Dicellograptus *cf.* sextans *J. Hall*
D. anceps *Nicholson*
D. elegans *Carruthers*
Diplograptus pristis *Hisinger*
Cryptograptus tricornis *Carruthers*
Climacograptus bicornis *J. Hall*
Lasiograptus *sp.*

Associated with these forms are however new species, as Diplograptus thielei and Climacograptus wellingtonensis at Mt Wellington, which give the faunules a provincially different aspect.

Turning now to the east side of the Atlantic basin, we find that the identity of a prominent graptolite zone in *Great Britain* with the Normanskill shale was early recognized by Lapworth [1879 and 1880]. He states [1880, p.198] of his "5. zone of Coenograptus gracilis Hall (or Dicellograptus sextans Hall)" which, by the way, is designated as the first of the "Upper Ordovician":

This is typically developed in the lower portion of the Glenkiln shales of the south of Scotland. It is the first of the Dicellograptidian zones, and is well particularized by the peculiar genus Coenograptus. Only a single Dichograptid (D. superstes Lapworth) survives. Dicranograptidae are abundant. Dicranograptus zic-zac Lapworth, D. formosus Hopkinson, Dicellograptus sextans Hall, D. intortus Lapworth are peculiar, and several Diplograpti, such as Hallograptus bimucronatus Nicholson, H.? mucronatus Hall, Diplo-

graptus whitfieldi Hall etc. This zone was first recognized by Hall in the Normanskill beds of the valley of the Hudson.

In *Scania*, Törnquist and Tullberg have succeeded in establishing a detailed succession of zones. One of the zones of the Middle Graptolite shales (zone h, of Coenograptus gracilis) contains near Fogelsong among others:

Coenograptus gracilis Hall, Lasiograptus bimucronatus Hall, Dicranograptus nicholsoni Hopkinson, Dicellograptus cf. sextans Hall and several species of Diplograptus and Climacograptus.

In *France*, Barrois [1892, p.145] has identified Diplograptus foliaceus and D. angustifolius among graptolites from the sandstone of Saint-Germain-sur-Ille and tentatively referred the beds to the zone of Nemagraptus gracilis. The *Bohemian* graptolite shales have not furnished any characteristic forms of this zone.

Lapworth's claim of the identity of the faunas of the Nemagraptus gracilis zone of Great Britain and of the Normanskill shale of New York is finding additional verification in the *Monograph of British Graptolites* now being published, in which some of Hall's species not before recorded from Great Britain are described; and by the present publication in which the occurrence of an additional number of forms originally described by Lapworth from the corresponding British beds is recorded from New York. The graptolite lists of the horizon on both sides of the Atlantic are thus approaching to identity. Still, there remains a considerable number of species peculiar to each of the two regions and there exist also some discrepancies in the range of forms which call for explanation. Thus Amphigraptus divergens Hall, which is known here only from the Normanskill shale, is restricted in Great Britain to the zone of Pleurograptus linearis, which is the second of the zones succeeding that with Nemagraptus gracilis. Since it is a rather rare form in both the Normanskill zone and that of Pleurograptus linearis, it is probable that its complete range is not yet known on either side. As in this instance, it would be in others perhaps rash to infer migrations from slight differences — unless

supported by accumulative evidence — where one has to deal with faunas of obviously world-wide distribution. This does not exclude that there existed slight provincial differences between these pelagic faunas of the oceanic basins — a fact which we have already emphasized in the discussion of the distribution of the Deepkill graptolite faunas — and a possible concomitant exchange of forms that originated in the different basins.

The Normanskill graptolite shales of the Appalachian geosyncline and those of the basins of Arkansas, Indian Territory and of the Rocky mountain region are separated by the vast expanse of synchronous Trenton limestones extending across the intervening area. The Normanskill shale and the Trenton limestone not only approach so closely along the Quebec barrier as to come practically into contact, but they seem actually to overlap each other at times as indicated by the occurrence of Trenton conglomerate on Rysedorph hill and by certain observations of the writer in Saratoga and Washington counties. It would then seem that the Normanskill graptolite fauna of the Levis channel would have had, at least occasionally, ample opportunity to spread westward across the barrier and it should be expected, in traces at least, in the Trenton limestone.

The *Trenton limestone* has furnished the following faunule:

1 Dictyonema neenah *Hall*
2 Dictyonema canadensis (*Whiteaves*)
3 Thamnograptus affinis *Whiteaves*
4 Diplograptus amplexicaulis (*Hall*)
5 Climacograptus typicalis *Hall*

Of these the first two are forms not represented in the Normanskill shale, the first is from the "Trenton limestone" of Wisconsin, the second, third and fifth are from the Galena-Trenton limestones of the Lake Winnipeg region which according to Whiteaves [1897, p.135] "most probably represent the whole of the Utica and Trenton formations, inclusive of the Galena." This would explain the appearance of Climacograptus typicalis in the list. The Trenton limestone of New York has furnished the single species of Diplograptus amplexicaulis which occurs quite frequently in certain layers of the middle and upper Trenton at Trenton Falls and Middleville and is characteristic of a zone that is

younger than the Normanskill shale [*see postea*]. It can therefore be said that the Trenton limestone has thus far not furnished any evidence whatever of the presence of the Normanskill graptolite fauna in the limestone-depositing areas of the epicontinental sea.

2 Magog shale (zone of Diplograptus amplexicaulis)

Upper Dicellograptus subzone Gurley

Lapworth [1887, p.173] distinguished two subfaunas of the "Marsouin River or Normanskill fauna" of Canada, viz:

Subfauna A *The Coenograptus zone of Griffin Cove and the Marsouin river* answering to the Middle Llandeilo beds of Great Britain, to the Glenkiln beds of Scotland, etc.

Subfauna B *The Cove Fields and Orleans subfauna;* apparently destitute of Coenograptus gracilis, and answering to the highest Llandeilo or lowest Caradoc beds of England.

Of the Cove Fields and Orleans subfauna, it is stated that it "shows evidence of a transition into the Utica-Lorraine Graptolitic fauna of the Mohawk valley, New York, and of Lake St John, Canada. The following species are cited from the two mentioned localities.

1 Cove Fields, near Quebec city:

Diplograptus foliaceus *Murchison var.*
D. amplexicaulis ? *Hall*
D. truncatus (?) *Lapworth*
D. euglyphus *Lapworth* (?)
Corynoides calycularis *Nicholson*
Dicellograptus *sp.*
Climacograptus *two sp.*
C. bicornis *Hall*
Cryptograptus tricornis *Carruthers*
Dicranograptus tardiusculus (?) *Lapworth*

2 Island of Orleans, near Quebec city:

Dicranograptus ramosus (*Hall*) *var.* spinosus *Lapworth*
Climacograptus scharenbergi *Lapworth*
C. bicornis *Hall*
Diplograptus foliaceus *Murchison*

Gurley secured a large collection near Magog[1] at the north end of Lake Memphremagog, at the boundary of Quebec and New Hampshire,

[1] A smaller list of the Magog fauna has also been given by G. M. Dawson [Geol. Sur. Can. Rep't, v. 7, 1894, Ap. 133J]. This is copied by Richardson [1902, p.67] who figures a characteristic slab of this graptolite shale.

and lists from this locality [1896, p.296] which, as he states, furnishes the largest fauna of the subzone:

Dicranograptus nicholsoni *var.* arkansasensis *Gurley*
D. ramosus *Hall*
Climacograptus caudatus *Lapworth*
id. var. laticaulis *Gurley*
C. kamptotheca *Gurley*
C. oligotheca *Gurley*
C. scharenbergi *Lapworth*
C. wilsoni *Lapworth*
Diplograptus foliaceus *Murchison*
D. peosta *mut.* perexcavatus *nov.* ?
D. truncatus ? *Lapworth*
Cryptograptus tricornis (*Carruthers*)
Lasiograptus mucronatus (*Hall*)
Dendrograptus unilateralis *Gurley*
D. *sp.*
Dictyonema *sp. incert.*
Thamnograptus barrandi *Hall*
Corynoides calicularis *Nicholson*

It will be noticed that these faunules observed in Canada are essentially relict faunules of the climacteric fauna of the zone of Nemagraptus gracilis. The Didymograptidae have vanished entirely and the Dicranograptidae almost; only the long range forms Dicranograptus ramosus and nicholsoni are still observed, and the Diplograptidae can be said to hold now almost entirely the field with the genera Diplograptus, Climacograptus and Cryptograptus. The graptolite shales of New York or of any other part of the United States have not yet furnished a typical representation of this zone,[1] but we have in this State several faunules which clearly are intercalated between the Normanskill and Utica shales and obviously either represent fragmentary faunules of this zone or minor subzones of the same.

As the most important of these we regard the *shales with Diplograptus amplexicaulis var. pertenuis* exposed in various localities (Watervliet arsenal etc., *see* N. Y. State Mus. Bul. 42, p.528) denoting a belt of rock that passes along the Hudson between the cities of Troy and Albany and is intercalated between Normanskill shales on the east and Utica shale on the west. Lapworth has also commented [*op. cit.* p.172] on "the presence of a form identical with, or closely allied to, the G. amplexicaulis of

[1] Gurley thought at first to recognize it in the graptolite shales of Arkansas [1892, p.403], but later [1896, p.305] changed his view regarding the proper correlation of that fauna.

Hall" in the Cove Fields exposure and inferred that this occurrence might point to a homotaxy with the lowest zones of the Black River or Trenton limestones. We have, in the paper cited before, adduced evidence to demonstrate the approximately middle Trenton age of this subzone. In some of the localities of the latter, as at Rusher's quarry at Troy, the form is associated with Corynoides gracilis.

We would also refer here to the exposure of graptolite shale at the falls of the Hudson river at *Sandy Hill*, already known to the geologists of the first survey as Baker's falls and yet requiring more detailed study. Here a shale lying between Trenton limestone and Utica shale contains:

Diplograptus amplexicaulis (*Hall*)
Climacograptus typicalis *mut.* spinifer *nov.*
Glossograptus (?) eucharis (*Hall*)
Corynoides gracilis *Nicholson*
Trocholites ammonius *Conrad*

By its lithologic aspect one would feel inclined to place this shale with the overlying Utica beds, but there is little doubt that the boundary between the Trenton limestone and Utica shale around the Adirondack plateau — or at least east of it — is by no means synchronous but shifting and that the shale in some places represents deposits of late Trenton age (and perhaps vice versa) and this faunule would serve to corroborate this view.

A similar case pointing to the like view is that of a faunule collected by the writer at *Van Schaick island* between Cohoes and Troy [*see* Bul. 42, p. 524]. This consists of the graptolites:

Chaunograptus ? rectilinea *nov.*
Diplograptus foliaceus *mut.* vespertinus *nov.*
Cryptograptus tricornis *mut.* insectiformis *nov.*
Climacograptus putillus (*Hall*)

These fossils are associated with Cameroceras proteiforme (Hall), Leptobolus insignis Hall and Schizocrania filosa Hall. It will be seen that this is in all respects a good Utica shale fauna, except for the occurrence of the distinctly gerontic mutation of Cryptograptus tricornis. The latter species has never been observed in the Utica shale and its occurrence in this association indicates a transitional subzone between the Magog and Utica shales.

The same can be said of another at present also isolated fauna that has been found by the writer at the power house below *Mechanicville* on the right bank of the Hudson river [*see* Bul. 42, 1901, p.519]. It consists of a large number of brachiopods, mollusks and crustaceans partly denoting Utica, partly Trenton age, and the following graptolites:

Corynoides curtus *var.* comma *nov.*
Diplograptus foliaceus *Murchison*
Glossograptus quadrimucronatus *var.* approximatus *nov.*
Climacograptus caudatus

Climacograptus caudatus is restricted in Europe to the zone of Dicranograptus clingani, which corresponds to the Magog shale and lies between the zones of Nemagraptus gracilis (Normanskill shale) and Pleurograptus linearis (Utica shale). It has also been found in the Magog shale itself. Its occurrence in the Mechanicville shale together with a mutation that is restricted to this bed (Corynoides curtus var. comma) indicates a transitional subzone lying somewhere near the boundary of the Magog and Utica shales. We will for the present designate it as the subzone of the two mentioned forms.

The Climacograptus caudatus has also been found by the writer in shales dredged from the Hudson river at the city of Troy. The location of this latter shale indicates its stratigraphic proximity to the shales with Diplograptus amplexicaulis, our principal representative of the Magog shale.

In *Great Britain* Lapworth [1880, p.198] has distinguished a *zone of Dicranograptus clingani Carruthers* which follows that of Nemagraptus gracilis. It is in its turn succeeded by the zone of Pleurograptus linearis Carruthers, which roughly corresponds to our Utica shale [*see postea*]. By its relative stratigraphic position the Magog shale may, therefore, be expected to correspond to the zone of Dicranograptus clingani Carruthers. Although no complete fossil lists of the British zones, that would admit positive correlation are at hand, the presence, in the Magog shale, of such a form as Climacograptus caudatus that in Great Britain is restricted to this zone, leaves little doubt of their homotaxy.

Tullberg [1882, p.18] has distinguished in *Scania* three subzones of that of Dicranograptus clingani Carruthers, the lowest of which alone carries Climacograptus caudatus while the highest one contains Leptograptus flaccidus, Diplograptus foliaceus and Climacograptus bicornis. It is, therefore, possible that his last subzone already corresponds to our lower Utica shale. Olin has also lately recorded [1906] the occurrence of Glossograptus quadrimucronatus in the Clingani zone in the neighborhood of Jerrestad in Scania and for this reason has suppressed Tullberg's zone of G. quadrimucronatus. It therefore becomes quite probable that the boundaries of our Magog and Utica shales do not exactly correspond to those of the zones of Climacograptus clingani and Pleurograptus linearis.

3 Utica shale (zone of Glossograptus quadrimucronatus and Climacograptus typicalis)

The graptolite fauna of the Utica shale in New York and the adjoining areas of Canada and Ohio consists of:

Callograptus compactus (*Walcott*)
Dictyonema arbuscula *Ulrich*
Mastigograptus tenuiramosus (*Walcott*)
M. simplex (*Walcott*)
M. gracillimus (*Lesquereux*)
M. arundinaceus (*Hall*)
M. circinalis *nov.*
Chaunograptus gemmatus *nov.*
C. ? rectilinea *nov.*
Leptograptus annectans (*Walcott*)
Leptograptus flaccidus (*Hall*)
Pleurograptus linearis (*Carruthers*)
Dicranograptus nicholsoni *Hopkinson*
D. spinifer *Elles & Wood*
Corynoides curtus *Lapworth*
id. var. comma *nov.*
Diplograptus foliaceus *mut.* vespertinus *nov.*
Glossograptus quadrimucronatus (*Hall*)
id. var. approximatus *nov.*
id. var. cornutus *nov.*
Glossograptus ? eucharis (*Hall*)
Climacograptus typicalis *Hall*
C. putillus (*Hall*)
C. bicornis *Hall*
Lasiograptus bimucronatus *mut.* timidus *nov.*

This fauna is markedly different from that of the Normanskill shale of New York and also well differentiated from that of the Magog shale. Its relict element from these preceding zones is very small. It consists of one

species (Climacograptus bicornis) and a few mutations or distinct derivatives viz, Leptograptus flaccidus heralded by L. flaccidus mut. spinifer, Dicranograptus nicholsoni with the prenuncial mutations diapason and parvangulus; D. spinifer, Diplograptus foliaceus mut. vespertinus, Lasiograptus bimucronatus mut. timidus. The common and characteristic graptolites of the Utica shale are all new forms; the most notable of these are:

Corynoides curtus *Lapworth*	G. ? eucharis (*Hall*)
Glossograptus quadrimucronatus (*Hall*)	Climacograptus typicalis *Hall*

The last three cited graptolites the collector meets in almost every outcrop of typical Utica shale in both Canada and New York. Leptograptus flaccidus, Dicranograptus nicholsoni and Climacograptus putillus are very common in certain localities, but absent in others and apparently of more restricted horizontal and vertical distribution. Altogether, it is by no means to be assumed that the entire above cited assemblage of graptolites is found in every locality; on the contrary, the faunules of the localities are of so different aspects that the presence of subhorizons, only to be established by careful stratigraphic work, can not be doubted. The following lists from some representative localities in New York State will demonstrate this fact.

The Utica shale of the Mohawk valley, which from the presence of the type section in that valley is to be considered as representing the typical development of the formation, contains the following graptolites:

Chaunograptus gemmatus *nov.*	G. ? eucharis (*Hall*)
Dicranograptus nicholsoni *Hopkinson*	Climacograptus typicalis *Hall*
D. spinifer *Elles & Wood*	C. putillus (*Hall*)
Corynoides curtus *Lapworth*	Lasiograptus bimucronatus *mut.* timidus *nov.*
Diplograptus foliaceus *mut.* vespertinus *nov.*	
Glossograptus quadrimucronatus (*Hall*)	

There are again distinct differences in the distribution of these forms recognizable in the Mohawk valley. Dicranograptus nicholsoni and D. spinifer have only been found in one locality, i. e. Fort

Plain.[1] The shales at Dolgeville, which are in the lower third of the Utica shale contain only:

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[1] This is the "Dicranograptus ramosus," recorded by Professor Whitfield from the mouth of the Oxtungo creek near Fort Plain, N. Y. He cites from this locality [1877, p.19] Graptolithus (Monograptus) serratulus Hall, G. (Diplograptus) pristis Hall, G. (Climacograptus) bicornis Hall and G. (Dicranograptus) ramosus Hall; and infers from this faunule the homotaxy of the Normanskill and Utica shales. The occurrence of Didymograptus serratulus has not been verified by later collectors and Lapworth remarks [1886, p.171] that the form thus identified was possibly a Leptograptus.

Likewise the list of Utica graptolites published by Walcott [1890, p.339] which is obviously based on Whitfield's original determinations has not been verified by the collections at our disposal. The following species are named:

1 Didymograptus serratulus *Hall*
2 Dicellograptus divaricatus *Hall*
3 Dicranograptus ramosus *Hall*
4 Climacograptus bicornis *Hall*
5 C. typicalis *Hall*
6 C. scalaris *Hall*
7 Diplograptus pristis *Hall*
8 D. putillus *Hall*
9 D. mucronatus *Hall*

Dr Gurley states in a manuscript note in regard to this list:

"This list was compiled by me at Mr Walcott's request and to it I contributed my quota of errors. (Nos. 2 and probably 3, which latter is not otherwise accounted for.) The remainder were copied from a list in a previous paper by Mr Walcott, (The Utica Slate and Related Formations, 1879, p.34, 35) which in its turn was compiled from the 'authorities.'"

A similar faunule, viz:

Climacograptus bicornis *Hall*
Dicranograptus ramosus *Hall*
Diplograptus mucronatus *Hall*

has been recorded by Beecher [1883, p.78] from Black rock pond near Observatory hill, Albany, N. Y. This is associated with a fair-sized mollusk-fauna indicating very late Utican age. An inspection of the collection which is in the State Museum has shown that the graptolite faunule consists of:

Climacograptus putillus (*Hall*)
Glossograptus ? eucharis (*Hall*)
Diplograptus *sp. ind.* (probably foliaceus)

It is, hence, in full accord with the associated forms and the graptolite faunules of the neighborhood.

Chaunograptus gemmatus *sp. nov.*
Glossograptus quadrimucronatus (*Hall*)
G. ? eucharis (*Hall*)
Climacograptus bicornis *Hall*
C. typicalis *Hall*

while the shales in Flat creek at the south side of the Mohawk, belonging to the upper third afford: C. putillus and Lasiograptus bimucronatus mut. timidus.

The most peculiar distribution of all of these forms has Corynoides curtus which is common in the outcrops of the Appalachian trough [*see postea*], but in the Mohawk valley has been traced only a short distance westward (to Amsterdam) and has never been seen by the writer in collections of the Utica shale of the middle and upper Mohawk valley, the outcrops west of the Adirondack region or of the Cincinnati and Maquoketa shales.

The faunule of Holland Patent, which has become known by Walcott's investigation [1879] has again a different aspect. It consists of:

1 Callograptus compactus (*Walcott*)
2 Mastigograptus tenuiramosus (*Walcott*)
3 M. simplex (*Walcott*)
4 Leptograptus annectans (*Walcott*)
5 Pleurograptus linearis (*Carruthers*)
6 Dicranograptus nicholsoni *Hopkinson*
7 Diplograptus foliaceus *mut.* vespertinus *nov.*
8 Glossograptus quadrimucronatus (*Hall*)
9 G. ? eucharis (*Hall*)
10 Climacograptus typicalis *Hall*
11 C. putillus (*Hall*)
12 Lasiograptus bimucronatus *mut.* timidus *nov.*

Nos. 1, 3 and 5 of this list have thus far not been recorded from any other locality in the United States; the two species of Mastigograptus are also known from Canada; and Pleurograptus linearis, which is known to me only in a single specimen from Holland Patent, marks a zone in the Hartfell shales of Scotland and Scania. It is probably proper to consider this faunule as typically representing the European *zone of Pleurograptus linearis* [*see postea*].

The Utica shale faunules of the Appalachian trough in New York form a group by themselves[1] by the common occurrence of Corynoides

[1] They have been fully cited with their associated nongraptolitic forms by the writer in N. Y. State Mus. Bul. 42, 1901, p.519 ff.

curtus in nearly all of them. One of the most important of these faunules is that from the Rural cemetery near Albany. It consists of:

Mastigograptus circinalis *sp. nov.*	G. ? eucharis (*Hall*)
Corynoides curtus *Lapworth*	Climacograptus putillus (*Hall*)
Glossograptus quadrimucronatus *var.* cornutus *nov.*	

This interesting faunule stands apart from all others by the peculiar and striking variety of G. quadrimucronatus and by Mastigograptus circinalis, two forms that have not been found elsewhere, while on the other hand Climacograptus typicalis is entirely absent. It most probably represents a separate subzonal association.

The other localities as e. g. the Penitentiary at Albany and Black creek at Voorheesville have furnished:

Corynoides curtus *Lapworth*	Climacograptus typicalis *Hall*
Glossograptus quadrimucronatus (*Hall*)	C. putillus (*Hall*)
G. ? eucharis (*Hall*)	

This faunule can be considered as a typical one for the Utica shale of this belt.

The transition beds from the Trenton limestone to the Utica shale exposed at the lake shore at Panton, Vt., consisting of alternating limestones and shales which contain in the limestones a Trenton and in the shales a Utica fauna, have furnished to the writer:

Corynoides curtus *Lapworth*	Climacograptus putillus (*Hall*)
Glossograptus quadrimucronatus (*Hall*)	Lasiograptus bimucronatus *mut.* timidus *nov.*
G. ? eucharis (*Hall*)	

These forms are among the earliest of the Utica graptolite fauna. Climacograptus typicalis seems to come in a little later.

A tunnel of the New York and Lake Erie Railroad being constructed at Otisville through the Shawangunk mountains at the New York and New Jersey boundary has furnished to the writer from shale, directly underlying the Upper Siluric Shawangunk grit, besides specimens of Schizocrania filosa Hall:

Glossograptus quadrimucronatus (*Hall*) var.
Climacograptus bicornis *Hall*
C. typicalis *Hall*
C. putillus (*Hall*)

This occurrence indicates the continuation of the Utica shale belt of the Hudson river valley into New Jersey, although the presence of the Utica shale fauna has not yet been recorded from the "Hudson River slate" of that State. Collections made in Pennsylvania by Dr Ulrich, which I have had occasion to see, leave no doubt of the farther extension of the Utica shale into that part of the Appalachian trough.

The extensive Utica shale exposures of the Lake Champlain region are, as Professor Perkins correctly remarks, singularly barren in fossils and especially in graptolites. The long continuous exposures of Grand isle yielded to the present writer only a few specimens of Climacograptus typicalis.[1] On the New York side of the lake only a few small patches of Utica shale remain, the most notable of which are those near Addison Junction and Rouse Point.

In *Canada* the faunas of the various localities have been carefully listed by Ami in his paper on the Utica Terrane in Canada [1892]. Glossograptus quadrimucronatus, G. ? eucharis and Leptograptus flaccidus appear in nearly all of the lists; besides Mastigograptus simplex, Climacograptus bicornis ?, C. scharenbergi ?, C. sp. and Diplograptus pristis. We have had occasion to observe the presence of both Climacograptus typicalis and C. putillus in Canadian Utica shale and since Ami comments on the difficulty of determining the Climacograpti [*ibid.* p.16], it is quite obvious that his tentative identifications refer to these two species which, at that time being not yet described and known only from Hall's enlargements of fragments of the rhabdosome, were not easily recognized. Mastigograptus tenuiramosus I have seen in Canadian specimens sent me by Professor Whiteaves.

[1] Professor Perkins [1904, p.106] records Climacograptus bicornis and Diplograptus pristis from the Utica shale of Grand isle.

The collection from the Utica shale of *Cincinnati* kindly loaned to me by Dr Ulrich contains:

Dictyonema arbuscula (*Ulrich*)
Mastigograptus tenuiramosus (*Walcott*)
M. gracillimus (*Lesquereux*)
Chaunograptus gemmatus *sp. nov.*
Leptograptus annectans (*Walcott*)
Dicranograptus nicholsoni *Hopkinson* (Dicr. ramosus *auct.*)
Climacograptus typicalis *Hall*
C. putillus (*Hall*)
Lasiograptus bimucronatus *mut.* (Diplograptus whitfieldi *et* spinulosus *auct.*)

It will be observed that this is in all respects a true though greatly depauperated Utica graptolite fauna. Especially notable is the absence of Glossograptus quadrimucronatus, G. ? eucharis, Climacograptus bicornis and of the later mutation of Diplograptus foliaceus. According to Nickles [1902, p.68 ff]

Mastigograptus gracillimus (*Lesquereux*)
Climacograptus typicalis *Hall*
C. putillus (*Hall*)

range through the formation while

Mastigograptus tenuiramosus (*Walcott*)
Dicranograptus nicholsoni *Hopkinson*
Lasiograptus bimucronatus *mut.* timidus *nov.*

are restricted to the lower Utica and Dictyonema arbuscula to the middle third of the formation.[1]

On the other side of the Cincinnati geanticline or parma, in Wisconsin, Minnesota, Iowa and Missouri, the *Maquoketa shale* is currently considered as the equivalent of the Utica shale of New York. Winchell and Schuchert [1895, p.81 ff] cite Diplograptus pristis ? (Hisinger) Hall and

[1] Ulrich and Schuchert [1901, p.645] consider the middle and upper Utica of Nickles's Cincinnati section as equivalent to the Frankfort shales, "the typical Utica barely reaching that point, though something like 300 feet thick in northwestern Ohio." The presence of Climacograptus typicalis and C. putillus in these beds does not seem to support this view, since the former is not known here to pass beyond the Utica shale and the latter only enters the lower or transitional Frankfort beds. It must, however, be conceded that the graptolite faunas of the Frankfort and Lorraine shales in New York are still very imperfectly known, and that both forms may possess longer ranges than hitherto observed.

D. putillus Hall from it. The former determination refers quite obviously to specimens of Hall's species D. peosta, originally described from this region but not figured until lately. We have before us a collection from the Maquoketa shale at Spencer, 20 miles south of St Louis secured by Dr Ulrich and containing a small new Climacograptus (C. ulrichi), related to C. typicalis; and representative collections from the better known graptolite localities in Minnesota, Wisconsin and Iowa, kindly secured for us by Professor Sardeson. These indicate the presence of a slightly greater faunule than has hitherto been recorded. One of the beds of Maquoketa shale contains a small graptolite in such numbers that it has been distinguished as the Diplograptus bed [*see* Sardeson, 1897, p.24]. Specimens from the exposure of this bed at Graf, Ia. contain D. peosta in plastic preservation, exactly like Hall's type of that species (from Maquoketa creek) in the American Museum of Natural History. Fragments of the Diplograptus bed at Elgin, Ia. contain Glossograptus ? eucharis in great number and typical development and a few specimens of G. quadrimucronatus. The well known locality at Granger, Minn. furnishes in Diplograptus bed no. 11:

Diplograptus peosta *Hall*, the prevailing form
Climacograptus putillus (*Hall*)
Lasiograptus bimucronatus *mut.* timidus *nov.*

A few rock specimens from the Triplecia bed (=no. 10) near Wykoff, Minn. contain Diplograptus peosta and others from the Leptaena bed (=no. 13) Glossograptus quadrimucronatus.

The complete graptolite fauna of the Maquoketa beds would hence consist of:

Diplograptus peosta *Hall*
Glossograptus quadrimucronatus (*Hall*)
G. ? eucharis (*Hall*)
Climacograptus ulrichi *nov.*
C. putillus (*Hall*)
Lasiograptus bimucronatus *mut.* timidus *nov.*

On the whole, this association can properly be considered as a fragmentary Utica shale fauna, but it is to be noted that the most frequent form,

Diplograptus peosta Hall, is in New York State not a Utica but a Lorraine fossil and that the others are species which here apparently range through the greater part of the Utica shale and partly beyond it. It is therefore very probable, from this evidence at least, that the Maquoketa shale is equivalent only to the last part of our Utica shale and to a part of our Lorraine. In this connection it is also important to note that the characteristic Utica shale graptolite, Climacograptus typicalis, which in its typical expression is not present in the Maquoketa shale, is reported by Winchell and Schuchert [*op. cit.* p.82] from the Galena limestone at Mantorville and Weisbach's dam near Spring Valley, Minn., and listed by Winchell and Ulrich [*ibid.* p.CXI] as occurring in the Fusispira and Nematopora beds, i. e. at about the middle of the Galena dolomite. Since this form has not yet been observed below the Utica shale in the east, its earlier occurrence in the west suggests either that it migrated into the Utica shale region of the east from the northwest, which is contradictory to other evidence or that some of the upper Galena beds may be already of the age of our Utica shale which though apparently not supported by a comparison of the Galena and Utica litoral faunas is possible in view of the very different facies of the two and the corresponding differences in the faunal aspects. In such a case, it would be just the pelagic forms such as the graptolites from which we would expect positive evidence of synchrony.

Finally, the deposition of graptolitiferous shales seems also to have persisted into Utica time in the basin of *Arkansas*, where already the Beekmantown and Trenton graptolite zones are represented; at least, a slab of the National Museum collection [loc. 1243B] with Corynoides cf. curtus Lapworth, Climacograptus typicalis and Diplograptus sp. and the abundance of Climacrograptus putillus in another locality [Center sec. 13, 35, 17W] would suggest such an occurrence; and Dr Ulrich has even found in Indian Territory [*see postea*] a small graptolite fauna in shales overlying a bed with a Richmond fauna.

In *Europe* we find the equivalent of the Utica shale in the zone of Pleurograptus linearis. As stated before, it is probable that the two are

not exactly equivalent, Glossograptus quadrimucronatus, for instance, appearing already in the preceding zone of Climacograptus clingani. The time for exact correlation has, however, not yet arrived ; its prerequisites are a more detailed zonal study of our graptolite shales, notably the Utica shale, and the publication of complete fossil lists from the European graptolite beds.

The zone of Pleurograptus linearis is best developed in Scotland, where it abounds in Leptograptidae, and also well known in Scania [Lapworth, 1880, Olin, 1906]. Glossograptus quadrimucronatus is a prominent form of the zone in both Britain and Scandinavia.

The Utica shale is the first Champlainic graptolite shale which positively trangresses the western boundary of the Levis channel of the Appalachian geosyncline in New York and not only extends the full length of the Champlain basin connecting northward with the Ottawa basin, but also passes in a broad belt through the Mohawk valley around and over the south side of the Adirondack plateau and through the Black river basin on the west side of the Adirondacks, to Lake Ontario. In *Canada*, according to Ami [1892, p.17], the Utica shale is first met with north of the Island of Anticosti. "The Utica terrane occupies a more or less narrow and continuous belt along the north shore of the St Lawrence from Cape Tourmente, below Quebec, to Montreal whence the belt trends to the south, . . . crossing the boundary line." An interesting outlier is found far to the north of this belt in the Lake St John region or Upper Saguenay district. It is from this area that Hall's types of Glossograptus quadrimucronatus, G. ? eucharis and Leptograptus flaccidus, three of the most characteristic fossils of the Utica shale, have come.

Another outlier is found in the Ottawa basin. South of the international boundary the Utica shale follows the Champlain basin appearing in several small outliers on the New York side and in a broad belt on the Vermont side, especially on North Hero and Grand isle. At the upper Hudson the belt of outcrops divides, one branch continuing southward along the

Hudson and bending southeast with the whole belt of "Hudson River shale" north of the Highlands, its last outcrop being observed close to the New Jersey boundary. It probably continues in the Appalachian trough into Pennsylvania and Virginia. The other branch skirts the Adirondacks in the Mohawk valley and on their west side, disappearing beneath Lake Ontario to reappear in the Province of Ontario, crossing the same to Collingwood, "where it disappears beneath the waters of the Georgian bay and continuing north and west strikes numerous points, capes and islands about the great Manitoulin island dying out to the west and overlaid by newer and overlying formations."

The reappearance of Utica shale in the center of the Cincinnati geanticline at Cincinnati, and its tracing through Ohio (by well borings) demonstrate that the narrow belt of outcrops above delineated, does by no means indicate the whole distribution of this widely extended shale formation. The St John and Ottawa outliers show that the shale extended far on the "Canadian shield" and an outlier at Wells in the southern Adirondacks demonstrates that the Utica sea also swept at least a part of that plateau. The facts of this wide overlap combined with the shaly nature of the rocks and their greatly varying, often considerable thickness indicate that the Utica formation is the result of a great transgression of the sea brought about by a general depression of the northeastern part of North America. The transgressing sea came in from the northeast and brought with it a fauna with decided Atlantic elements; and currents developed which assisted in spreading the shales and the immigrating fauna far into the epicontinental sea.[1]

The facts of this transgression and enlargement of the northeastern communication with the Atlantic would seem to aid in explaining the differences between the graptolite faunas of the Utica shale and the underlying beds, and certain peculiarities in the areal distribution of some of the Utica shale graptolites as Corynoides curtus, Glossograptus

[1] *See* Matthew, Roy. Soc. Can. Trans. 10 : 15; Ruedemann, Amer. Geol. 1897. 19: 367–91; 21 : 75–81; Ulrich & Schuchert, N. Y. State Mus. Bul. 52. 1902. p.642.

quadrimucronatus and Leptograptus flaccidus. The first named graptolite fails to appear in the south and west of the Adirondacks; G. quadrimucronatus attains its largest size in the St John basin and is in New York represented in smaller forms and L. flaccidus which appears in prenuncial forms in the Normanskill shale and disappears in the Magog shale, did not, in the Utica age, again reach New York while it is abundant in Europe, the St John basin and lower Canada. The Cincinnati graptolite fauna when compared with that of New York appears so depauperated that it is easily recognized as being far away from the center of distribution.

It follows as a corollary from the conclusion of the transgression of the Utica shale and fauna from the northeast, that the boundary between the Trenton limestone and Utica shale is not a plane of synchrony in the State. The alteration of the Trenton into the Utica condition took place very gradually[1] and proceeded slowly westward. Sensitive horizon markers, such as the graptolites, may therefore with progressing refinement of the subdividing of the zones well be expected to fix the exact zonal planes of the boundary line between the Utica shale and Trenton limestone in the different regions by the establishment of the western extension of each subzone. The earlier subzones, for instance that of Mechanicville with Corynoides curtus var. comma and Climacograptus caudatus did, in the writer's opinion, extend but a very short distance west beyond the margin of the Appalachian trough and are overlapped by younger zones farther west. The before mentioned restriction of the areal distribution of Corynoides curtus to the lower Mohawk valley may

[1] This is indicated by numerous alternations of Trenton limestone with shales, as emphasized by Ami in Canada, by Perkins in Vermont and by Walcott [1879], Cushing and the writer [1897] in New York. Perkins [1904, p.107] has described the presence of an intermediate shale with both Trenton and Utica fossils from Grand isle; the writer found an alternation of limestone and shales, the latter with typical Utica graptolites, at Panton, Vt., and Cushing has distinguished the passage beds as a separate unit on the Little Falls sheet.

be also due to the greater age of the eastern Utica beds and their absence farther west, where they are probably represented by the lowest Trenton limestone.

4 Lorraine beds

The Lorraine beds, which term is here used to include both the Frankfort and Lorraine shales, are according to their graptolite fauna but little differentiated from the Utica shale; they contain little more than a relict fauna of the Utica shale and are bound closely to it by transitional beds.

The fauna of the Frankfort shale (subzone of Glossograptus quadrimucronatus *mut.* postremus) as represented at Waterford and Mechanicville, consists of:

Corynoides curtus *Lapworth*
Diplograptus foliaceus *mut.* vespertinus *nov.*
Glossograptus quadrimucronatus *mut.* postremus *nov.*
Climacograptus putillus (*Hall*)

The fauna of the Lorraine shale (subzone of Diplograptus foliaceus *mut.* vespertinus and Diplograptus peosta) consists in the Black river region of:

Diplograptus foliaceus *mut.* vespertinus *nov.*
Diplograptus peosta *Hall*

The faunule of the Frankfort shales is characterized by the gerontic character of its mutations of Diplograptus foliaceus and Glossograptus quadrimucronatus as being in a decadent stage; that of the Lorraine beds of the northwestern part of the State possesses in Diplograptus peosta a new element. This species has been here currently identified with Diplograptus amplexicaulis[1] and it seems indeed to be in its habit and character essentially a smaller D. amplexicaulis.

If the latter is the correct conception, this form would constitute another case of the reappearance of Trenton forms in the Lorraine beds.

The Lorraine shale, the typical exposure of which is in the Lorraine gorge south of Watertown in northwestern New York, is restricted to the

[1] James, Walcott, Whitfield and Hovey, Ruedemann, *see* under D. peosta.

west side of the Adirondack plateau. It extends in the Mohawk valley only as far east as Rome.

The Frankfort shale is apparently absent in the Champlain basin, but forms south of it a belt that crosses the Mohawk river at its mouth and thence extends westward on the south side of the Mohawk valley; and southward, disappearing under the Helderbergs but probably reappearing in the southern continuation of the Appalachian slate belt in New Jersey and Pennsylvania. From this distribution of the rocks the inference would suggest itself that the region east of the Adirondacks had become drained during Frankfort time, and the former marine connection of the Appalachian trough and western sea with the Atlantic basin had been interrupted there, the sea gradually withdrawing until at the beginning of Lorraine time it extended only as far as Rome. But it is quite as possible that the Frankfort beds of the Champlain region, being the last deposited and not protected by being infolded with the other rocks as in Saratoga and Albany counties, have all been abraded again. This view finds support in the fact of the presence of Lorraine beds directly north of the Champlain basin, south of Montreal, with a thickness of several hundred feet and a characteristic fauna [*see* Ami, 1900, p.159], and in the great thickness of the formation in Albany and Schenectady counties.

5 Zone of Dicellograptus complanatus Lapw.

Dr Ulrich's collection from Indian Territory contains a small graptolite faunule. It was obtained in the Sylvan shale of the Arbuckle mountains, and consists of

Dicellograptus *cf.* complanatus *Lapworth* Climacograptus mississippiensis *nov.*
Diplograptus crassitestus *nov.*

Dr Ulrich informs me that this interesting association overlies a Richmond fauna. It is hence probably representative of the youngest Lower Siluric beds of North America. This inference is to some extent borne out by the graptolitic evidence, notably by the presence of specimens of a Dicellograptus which, as far as their somewhat fragmentary character permits

of a conclusion, is identical with D. complanatus. The latter graptolite characterizes in Britain and Scandinavia the zone above that of Pleurograptus linearis. Lapworth [1880, p.298] describes this zone as follows:

Zone of Dicellograptus complanatus, Lapworth — The strata that lie between the zone of P. linearis, Carruthers, and the summit of the Ordovician system form in south Scotland two very distinct zones, though few Rhabdophora have yet been described from there. The lowest zone is that of *Dicellograptus complanatus*, Lapworth which contains but few peculiar forms in addition to its characteristic species. It is recognizable in the same stratigraphical position and affording the same fossils at Moffat (Barren Mudstones), at Girvan, in County Down, at Rostanga in Scania in the lower part of the Trinucleus schist, and in Westrogothia.

If our determination of this graptolite is correct, the beds in Indian Territory containing it would properly be correlated with this European zone.

Diplograptus crassitestus is a species with peculiarly coarse structure and reminds in its entire habit most strongly of D. trifidus Gurley, a form already occurring in the same region in Normanskill time.

Climacograptus mississippiensis is distinctly a later derivative of Climacograptus typicalis and points to the relationship of this zone to the preceding one. It is a close relative or vicarious form of C. latus [*see* under C. mississippiensis] which is found in the highest Champlainic (Ordovicic) graptolite zone of Europe, that of Dicellograptus anceps.

A summary of the analysis of the graptolite zones of the upper part of the Champlainic and their correlation with those of Europe is found in the correlation table at the beginning of this chapter.

1 SYNOPTIC TABLE OF THE DISTRIBUTION OF THE GRAPTOLITES OF THE MIDDLE AND UPPER CHAMPLAINIC (ORDOVICIC) OF THE UNITED STATES

	Trenton limestone	Normanskill shale	Magog shale	Utica shale	Lorraine shale	New York	Canada	Alabama	Cincinnati region	Arkansas	Miscellaneous	Great Britain: Glenkiln shale	Great Britain: Hartfell shale	Scandinavia	Australia	Other regions
1 Callograptus compactus (Walcott)				rr		x										
2 Ptilograptus poctai Ruedemann		rr				x										
3 Dictyonema neenah Hall	x										x[1]					
4 D. obovatum Gurley		x								x						
5 D. spiniferum Ruedemann		rr				x										
6 D. arbuscula (Ulrich)				r					x							
7 Odontocaulis hepaticus Ruedemann		r				x										
8 Desmograptus tenuiramosus Ruedemann		rr				x										
9 Thamnograptus capillaris (Emmons)		c				x						x			x?[2]	
10 Mastigograptus tenuiramosus (Walcott)				c	x	x	x[3]		x							
11 M. simplex (Walcott)				r		x	x ?									
12 M. gracillimus (Lesquereux)				x					x							
13 M. arundinaceus (Hall)				rr		x										
14 M. circinalis Ruedemann				r		x										
15 Chaunograptus gemmatus Ruedemann				rr		x			x							
16 C. ? rectilinea Ruedemann				rr		x										
17 Protovirgularia dichotoma ? McCoy		rr				x						x				
18 Didymograptus sagitticaulis Gurley		cc				x	x			x						Dease river, Brit. Col.
19 D. serratulus (Hall)		c				x				x		x				
20 D. subtenuis (Hall)		cc				x	x									
21 Azygograptus walcotti Lapworth		rr				x										
22 A. ? simplex Ruedemann		c				x										
23 Leptograptus flaccidus Hall mut. trentonensis Ruedemann		cc				x										
24 L. fl. var. spinifer mut. trentonensis Ruedemann		c				x										

25 L. fl. var. spin. mut. trifidus Ruedemann		rr				x										
26 L. annectans (Walcott)				r		x			x							
27 Syndyograptus pecten Ruedemann		r				x										
28 Pleurograptus linearis (Carruthers)				rr		x							x			
29 Amphigraptus divergens (Hall)		rr				x							x			
30 A. multifasciatus (Hall)		rr				x	x									Also New Jersey and Maine
31 Nemagraptus gracilis (Hall)		cc				x	x			x		x		x	x	
32 N. grac. var. surcularis (Hall)		c				x		x				x				
33 N. grac. var. crassicaulis Gurley		r				x										
34 N. grac. var. distans Ruedemann		r				x										
35 N. grac. var. approximatus Ruedemann		r				x										
36 N. exilis Lapworth		c				x										
37 N. ex. var. linearis Ruedemann		c				x										
38 Dicellograptus cf. complanatus Lapworth											x[4]		x			
39 D. mensurans Ruedemann		r				x		x								
40 D. divaricatus (Hall)		c				x	x			x		x			x[5]	
41 D. div. var. rectus Ruedemann		r				x										
42 D. div. var. bicurvatus Ruedemann		c				x										
43 D. div. var. salopiensis Elles & Wood		r				x						x				
44 D. div. var. rigidus Lapworth		r								x		x				
45 D. intortus Lapworth		rr				x	x					x				
46 D. gurleyi Lapworth		cc				x										
47 D. sextans (Hall)		cc				x	x					x		x	x	
48 D. s. var. tortus Ruedemann		c				x										
49 D. s. var. exilis Elles & Wood		r				x						x				
50 D. s. var. perexilis Ruedemann		r				x										
51 D. moffatensis var. alabamensis Ruedemann		cc						x								
52 D. smithi Ruedemann		cc						x								
53 Dicranograptus nicholsoni Hopkinson				c		x			x			x	x			
54 D. nich. var. parvangulus Gurley		cc	c			x	x			x						
55 D. nich. var. diapason Gurley		c				x										
56 D. nich. var. whitianus Miller											x[12]					
57 D. ramosus Hall		c				x	x			x		x	x			New Jersey
58 D. ram. var. arkansasensis Gurley		r								x		x ?				
59 D. spinifer Elles & Wood		c		r		x						x	x			
60 D. spin. var. geniculatus Ruedemann		r				x										
61 D. furcatus Hall		cc				x										
62 D. furc. var. exilis Ruedemann		r				x										
63 D. contortus Ruedemann		c				x										
64 Corynoides calicularis Nicholson		cc				x	x						x[5]	x		
65 C. gracilis Hopkinson			cc			x							x			

1 SYNOPTIC TABLE OF THE DISTRIBUTION OF THE GRAPTOLITES OF THE MIDDLE AND UPPER CHAMPLAINIC (ORDOVICIC) OF THE UNITED STATES *(continued)*

	TRENTON LIMESTONE	NORMANSKILL SHALE	MAGOG SHALE	UTICA SHALE	LORRAINE SHALE	NEW YORK	CANADA	ALABAMA	CINCINNATI REGION	ARKANSAS	MISCELLANEOUS	GREAT BRITAIN: GLENKILN SHALE	GREAT BRITAIN: HARTFELL SHALE	SCANDINAVIA	AUSTRALIA	OTHER REGIONS
66 C. grac. mut. perungulatus Ruedemann	...	cc	...	...	...	x	...	...	...	x						
67 C. curtus Lapworth	...	...	...	c	...	x	...	...	...	...	...	....	x	...	...	Also Vermont
68 C. curtus var. comma Ruedemann	...	...	...	c	...	x										
69 D. foliaceus (Murchison)	...	x	x	x	...	x	x	...	...	x	...	x	x	x	x	
70 D. fol. var. incisus Lapworth	..	cc	..	...	...	x	x									
71 D. fol. var. acutus Lapworth	...	cc	...	...	...	x	x	...	...	...	..	x				
72 D. fol. var. trifidus Gurley	...	x	...	...	...	...	...	...	...	x						
73 D. fol. var. alabamensis Ruedemann	...	cc	...	...	...	...	...	x								
74 D. fol. mut. vespertinus Ruedemann	...	...	...	x	x	x	...	...	...	...	x[7]					
75 D. crassitestus Ruedemann	...	...	...	...	...	...	...	...	...	...	x[4]					
76 D. amplexicaulis Hall	c	...	c	...	...	x										
77 D. ampl. var. pertenuis Ruedemann	...	...	cc	...	...	x										
78 D. angustifolius Hall	...	c	...	...	...	x	x	...	...	x	x[8]	x	....	...	...	New Jersey, Kicking Horse Pass, Rocky mts.
79 D. euglyphus Lapworth	...	c	x	...	...	x	x	...	...	...	x[8]	x	....	...	...	British Col.
80 D. eugl. var. pygmaeus Ruedemann	...	cc	...	...	...	x										
81 D. peosta Hall	...	...	...	...	c	x	...	...	...	...	...	....	....	...	...	Maquoketa beds in Minn. Wis. & Iowa
82 Glossograptus ciliatus Emmons	...	c	...	...	...	x	x	x	...	x	...	....	..	...	...	British Col. Maine
83 G. cil. mut. horridus Ruedemann	...	...	...	...	...	...	...	...	...	...	x[9]					
84 G. cil. var. debilis Ruedemann	...	c	...	...	...	x										
85 G. quadrimucronatus (Hall)	...	...	...	cc	...	...	x	...	...	...	...	....	x	x	x	
86 G. quad. var. approximatus Ruedemann	...	...	...	cc	...	x										
87 G. quad var. cornutus Ruedemann	...	...	...	cc	...	x										

88 G. quad. mut. postremus Ruedemann	...	..	...	...	cc	x										
89 G. whitfieldi (Hall)	...	cc	...	...	...	x	x	...	...	x	...	x				
90 G. ? eucharis (Hall)	...	...	..	cc	..	x	x	...	...	...	x[10]	...	...	...	...	Vermont, Iowa
91 Cryptograptus tricornis (Carruthers)	...	cc	x	...	...	x	...	x	...	...	...	x	x	...	x	Brit. Col. Bohemia
92 Cr. tric. mut. insectiformis Ruedemann	...	...	c	...	...	x										
93 Climacograptus typicalis Hall	...	...	...	cc	...	x	(x)	...	x							
94 C. typ. mut. spinifer Ruedemann	...	..	c	...	...	x										
95 C. ulrichi Ruedemann	...	...	...	...	...	...	...	...	...	...	x[11]					Minnesota, Iowa, Wisconsin
96 C. mississippiensis Ruedemann	...	...	...	..	...	...	...	..	...	...	x[4]	...	...	...	...	
97 C. putillus Hall	...	...	...	cc	...	x	...	(x)	x	x						
98 C. put. mut. eximius Ruedemann	...	...	cc	..	..	x										
99 C. parvus Hall	...	cc	...	..	...	x										
100 C. modestus Ruedemann	...	cc	...	...	...	x										
101 C. scharenbergi Lapworth	...	c	..	.	..	x	x	...	...	...	...	x	x	x		
102 C. bicornis Hall	...	cc	c	c	...	x	x	...	...	x	...	x	x	x	x	Virginia
103 C. antiquus Lapworth	...	x	...	...	...	..	x	..	...	x	..	x	...	...	...	Indian Ter. Brit. Col.
104 C. cf. oligotheca Gurley	..	...	x	..	...	...	x	..	...	x						
105 C. caudatus mut. posterus Ruedemann	...	...	...	c	...	x										
106 Retiograptus geinitzianus (Hall)	..	r	...	...	...	x	...	...	..	...	...	...	...	...	x ?	New Jersey
107 Lasiograptus mucronatus (Hall)	..	cc	..	..	...	x	x	...	...	x	...	x				
108 L. bimucronatus Nicholson	...	c	...	...	...	x	...	...	...	...	...	x	...	x		
109 L. b. mut. timidus Ruedemann	...	..	..	r	...	x										

NOTE. 1 Fox river, near Appleton, Wisconsin. 2 Doubtful, associated with Deepkill faunas. 3 Lorraine shale of County Chambly, Quebec. 4 Sylvan shales above the Richmond beds in Indian Territory. 5 Doubtful in New South Wales. 6 Also Moffat shales. 7 Probably also in Maquoketa beds in Minnesota. 8 Silver Peak quadrangle, Nevada. 9 Summit, Nev. 10 Maquoketa shale of Iowa. 11 Maquoketa shale of Missouri. 12 Belmont, Nev.

2 SYNOPTIC TABLE OF THE DISTRIBUTION OF THE GRAPTOLITES OF THE SILURIC (ONTARIC) OF THE UNITED STATES

	CLINTON BEDS	ROCHESTER SHALE	NEW YORK	MAINE	NIAGARAN OF OHIO, ILLINOIS, KENTUCKY	ONTARIO	OTHER REGIONS
1 Dendrograptus rectus Ruedemann	x	....	x				
2 Dictyonema pertenue Foerste	x	....	....	....	x		
3 D. scalariforme Foerste	x	....	x	....	x		
4 D. retiforme Hall	....	x	x				
5 D. gracile Hall	....	x	x	....	....	x ?	Mich.
6 D. polymorphum Gurley MS	....	x	x	....	....	x	
7 D. subretiforme (Spencer)	....	x	x	....	....	x	
8 D. areyi Gurley MS	....	x	x				
9 Desmograptus pergracilis (Hall & Whitfield)	....	....	....	....	x		
10 Cyclograptus rotadentatus Spencer	....	x	x	....	....	x	
11 Ptilograptus hartnageli sp. nov	x						
12 Inocaulis plumulosus Hall	....	x	x	....	....	x	
13 I. divaricatus Hall	....	....	....	....	x		
14 Acanthograptus walkeri Spencer	....	x	x	....	....	x	
15 Cactograptus crassus Ruedemann	x	....	x				
16 Palaeodictyota anastomotica (Ringueberg)	....	x	x				
17 P. clintonensis Ruedemann	x	....	x				
18 P. bella (Hall)	...	....	....	....	x	x	
19 P. bella mut. recta Ruedemann	x	....	x				
20 Chaunograptus novellus Hall	....	....	....	....	x		
21 Climacograptus scalaris (Hisinger) var. annulatus Ruedemann	....	....	....	x			
22 Monograptus clintonensis (Hall)	x	...	x				
23 M. priodon Bronn mut. chapmanensis Ruedemann	x	...	....	x			
24 Cyrtograptus ulrichi Ruedemann	....	....	....	....	....	....	Niagaran of Missouri
25 Retiolites geinitzianus Barrande *var.* venosus Hall	x	...	x				

5 Siluric (Ontaric)

The North American Siluric has afforded, in a very few localities it is true, a wealth of dendroid forms that is surpassing all that is known from that age in other parts of the world. Its dendroid fauna comprises 15 genera and 60 species and varieties.[1] It is however strangely barren in true

[1] The next largest is that of Bohemia with 8 genera and 26 species.

graptolites (Graptoloidea), which is the more remarkable when it is remembered what an elaborate succession of Upper Siluric graptolite zones has been worked out in Britain, Scandinavia and Bohemia by means of the Monograptidae. Only the Clinton beds of New York and Maine have yielded a few stragglers and in the Niagaran of the West a single species has been discovered. A lonely Monograptus from Northern Greenland, described by Etheridge [1878, p.577] as M. convolutus (Hisinger) var. coppingeri, raises the number of true graptolites of the Upper Siluric known from North America to six. It, however, so happens that these few forms are identical or so closely related with typical zone graptolites of Europe that they, so to say, illuminate by unexpected flashes of light the equivalency of parts of American Siluric formations with some of the European graptolite zones.

The Siluric graptolites of the United States are listed with their formations and areal distribution in the preceding synoptic table 2 on p.52.

1 *Upper Clinton beds* (*zone of Monograptus clintonensis Carruthers*)

The Clinton beds have furnished the following graptolites:

Dendrograptus rectus *nov.*
Dictyonema pertenue *Foerste*
D. scalariforme *Foerste*
Ptilograptus hartnageli *sp. nov.*
Palaeodictyota clintonensis *nov.*
P. bella (*Hall*) *mut.* recta *nov.*
Cactograptus crassus *nov.*
Monograptus clintonensis (*Hall*)
M. priodon *Bronn mut.* chapmanensis *nov.*
Retiolites geinitzianus *Barrande var.* venosus *Hall*

Dictyonema pertenue and scalariforme were first observed by Foerste in the Clinton group of Ohio; the last has also been found in the horizon of the Clinton iron ore in New York, together with Palaeodictyota clintonensis and P. bella mut. recta, two prenuncial forms of Niagaran species.

Monograptus clintonensis (Hall) and Retiolites geinitzianus Barrande var. venosus Hall, especially the former, occur in great profusion in the higher shales of the Clinton formation, apparently only above the Clinton iron ore bed. Monograptus clintonensis

is so nearly related to M. priodon that some authors have regarded it as but varietally different from the same. The typical European species of the two Clinton forms are associated in a certain horizon of the Middle Siluric, notably in Bohemia (zone of Monograptus priodon, Marr 1880, with Monograptus priodon, M. vomerinus, Cyrtograptus murchisoni, Retiolites geinitzianus), France (shales of Feuguerolles in the Normandy, Bretagne, *see* Barrois, 1892), Belgium (Malaise 1890), Norway (Björlykke) and Sweden (in Gothland). Lapworth's term *zone of Cyrtograptus murchisoni* (zone no. 17) is generally applied to this horizon in Europe. It forms in Britain the base of the Wenlock, but a correlation on this basis, of the Upper Clinton shale with the lowest Wenlock would be not fully warranted, since Retiolites geinitzianus appears in various regions (Silesia, Thuringia, Bretagne) already in a preceding zone which corresponds to the late Tarannon and Lapworth records Retiograptus geinitzianus and varieties of Monograptus priodon already from his zone 15 (of Monograptus exiguus Nicholson).

Another representative of the group of Monograptus priodon is here described as M. priodon var. chapmanensis. It occurs in a brown sandstone in Aroostook county in Maine and is evidently the species cited by Williams and Gregory as Monograptus priodon.[1]

The form from northern Greenland described by Etheridge as Monograptus convolutus var. coppingeri would indicate the presence in the far North of a shale of the age of the Rastrites beds of Europe, or of a horizon considerably below that of our Clinton graptolites.

Likewise the occurrence of a variety of Climacograptus scalaris in a sandstone in Maine points to the presence there of one of the earliest graptolite zones of the Siluric. C. scalaris is a cosmopolitan form, well known from the Baltic, Mediterranean — Bohemian basins and other parts of the Atlantic and has also been recorded from the western Pacific basin,

[1] Bailey [1901] has also recorded the occurrence of an undetermined Monograptus in several localities in New Brunswick.

but not before observed in North America.[1] Its finding in the northeastern corner of this continent is therefore of some interest. It is in Europe a form of the lowest Siluric, occurring there in the lower Rastrites shales. Tullberg [1882, p.76 ff] records it from the last zone of the Champlainic (Ordovicic) (zone of Diplograptus sp. and Climacograptus scalaris) and the first two of the Siluric (zones of Monograptus gryphus and M. gregarius), but Lapworth considers the first named zone as already constituting a basal zone of the Siluric. Törnquist records it from the first, third and fourth zones of the Scanian Rastrites beds.[2] While its occurrence in Maine without other associated species will thus not suffice to fix the exact horizon of the bed, it serves to demonstrate the presence there of the Rastrites beds of Europe and the development of the Siluric in a facies not known elsewhere in North America.

2 *Rochester shale and Lockport limestone*

The later Niagaran has in the United States afforded graptolites in only two localities, namely: in the Rochester shale of New York and the Bainbridge limestone of Missouri. In Canada a very rich dendroid fauna has been obtained in the Niagaran limestone of Hamilton, Ontario, and a Dictyonema in the Niagaran of the eastern provinces. The following is a list of the forms of the United States, here described:

1 Dictyonema retiforme *Hall*
2 D. gracile *Hall*
3 D. polymorphum *Gurley* ms.
4 D. subretiforme (*Spencer*)
5 D. areyi *Gurley* ms.
6 Desmograptus pergracilis (*Hall & Whitfield*)
7 Cyclograptus rotadentatus *Spencer*
8 Inocaulis plumulosus *Hall*
9 I. divaricatus *Hall*
10 Acanthograptus walkeri *Spencer*
11 Palaeodictyota anastomotica (*Ringueberg*)
12 P. bella (*Hall*)
13 Chaunograptus novellus *Hall*
14 Cyrtograptus ulrichi *nov.*

[1] The forms described by Hall as Graptolithus scalaris are scalariform aspects of Champlainic graptolites.

[2] See more detailed statement of range and distribution of this form in the species description.

All of these with the exception of nos. 6, 9, 12, 13 and 14 are from the Rochester shale of New York where they have been found in several localities, notably at Lockport and Middleport. Dictyonema areyi has been obtained only at Rochester. The greater part of the Rochester shale species of New York, viz, nos. 1, 2, 3, 4, 7, 8, 10, is also found in the limestone at Hamilton, thereby indicating the essential unity of the graptolite faunas of our Rochester shale and the Niagaran limestone at Hamilton. The latter has furnished a wonderfully varied fauna of dendroid graptolites which have been collected with untiring enthusiasm by Colonel Grant and described by Professor Spencer in several publications. Dr Gurley in his manuscript revision of the Dendroidea has still increased the number of species from Hamilton. Dr Spencer's list of Hamilton species is:

Phyllograptus ? dubius *Spencer*[1]
Acanthograptus granti *Spencer*
A. pulcher *Spencer*
Callograptus granti *Spencer*
C. minutus *Spencer*
C. multicaulis *Spencer*
C. niagarensis *Spencer*
Calyptograptus cyathiformis *Spencer*
C. micronematodes *Spencer*
? radiatus *Spencer*
subretiformis *Spencer*
Cyclograptus rotadentatus *Spencer*
Dendrograptus dawsoni *Spencer*
D. simplex *Spencer* (preoccupied=S. dubius *Miller*)
D. frondosus *Spencer*
D. praegracilis *Spencer*
D. ramosus *Spencer*
D. spinosus *Spencer*
D. (Chaunog.) novellus *Hall*
Dictyonema expansum *Spencer*
D. gracile *Hall*
D. pergracile *Hall & Whitfield*
D. splendens *Billings*
D. tenellum *Spencer*
D. websteri *Hall*
Ptilograptus foliaceus *Spencer*
Rhizograptus bulbosus *Spencer*
Inocaulis bellus *Hall & Whitfield*
I. cervicornis *Spencer*
I. diffusus *Spencer*
I. divaricatus *Hall*
I. phycoides *Spencer*
I. plumulosus *Hall*
I. ? problematicus *Spencer*
I. ramulosus *Spencer*
I. walkeri *Spencer*
Thamnograptus bartonensis *Spencer*
T. ? multiformis *Spencer*

This grand outburst of Dendroidea in the Upper Niagaran beds is,

[1] Not a graptolite

with our present knowledge, of little value for correlation with the European graptolite zones, since it is obvious that most, or probably all of these forms were sessile to the bottom of the sea and hence living under conditions that were totally different from those surrounding the Graptoloidea or true graptolites. It is, however, possible that a revision and more detailed description of this fauna will furnish the means of a closer comparison with the numerous Dendroids made known from the Siluric of Bohemia.

Of greater interest, as far as concerns a possible correlation with extra-American graptolite horizons, is the single representative of the Graptoloidea of the Upper Niagaran, viz, Cyrtograptus ulrichi sp. nov. It comes from the upper part of the Bainbridge limestone (corresponding to late Niagaran), Bainbridge, Cape Girardeau county, Mo. and is the first Cyrtograptus discovered on this continent. It is very closely related to or possibly a vicarious form of C. lundgreni Tullberg. Since that form is restricted to the zone with C. carruthersi which is the uppermost zone of the Middle Siluric, and would hence well correspond to the location of our graptolite in the Missouri beds, the inference of the presence of that graptolite zone in the Mississippi basin cannot be far from the truth.

6 Devonic

In contradiction to the old axiom that the graptolites are Siluric index fossils *par excellence*, the American Devonic has furnished an ever increasing list of graptolites until the number has now grown to 11 from the United States and 2 from Canada. The following is a tabulation of the forms from the United States:

3 SYNOPTIC TABLE OF THE DISTRIBUTION OF THE GRAPTOLITES OF THE DEVONIC OF THE UNITED STATES

	NEW SCOTLAND BEDS	ONONDAGA LIMESTONE	HAMILTON BEDS	NEW YORK	DEVONIC OF WEST	OTHER REGIONS
1 Dictyonema crassum Girty	x	....	....	x		
2 D. leroyense Gurley ms	....	x	....	x		
3 D. megadictyon Gurley ms	....	x	....	x		
4 D. perradiatum Gurley ms	....	x	....	x	....	Ontario, Canada
5 D. fenestratum Hall	....	....	....	..	x	
6 D. hamiltoniae Hall	....	....	x	x		
7 Ptiograptus percorrugatus Ruedemann	....	....	....	....	x	
8 Desmograptus becraftensis Ruedemann	x	....	....	x		
9 D. cadens (Hall)	....	....	x	x		
10 D. vandelooi Ruedemann	....	....	x	x		
11 Monograptus beecheri Girty	x	....	....	x		

From Canada have become known: Dictyonema splendens Billings and Chaunograptus gracilis Clarke, both from the early Devonic of Gaspé, Province of Quebec. Of the 11 species, credited to the United States, no less than 9 forms are derived from the Devonic rocks of New York. Two of these, Dictyonema crassum and Desmograptus becraftensis, are found in the New Scotland beds of Becraft mountain, the former also in those of the Helderbergs. The New Scotland beds of the Indian Ladder have also furnished the single representative of the Graptoloidea, Monograptus beecheri. Three species, viz, Dictyonema leroyense, D. megadictyon and D. perradiatum are from the Onondaga limestone of Leroy in western New York, the last also being observed in the same formation in Ontario, Canada.

The Hamilton beds of New York contain three species of graptolites. Two Devonic types, Dictyonema fenestratum and Ptiograptus percorrugatus, are from western beds.

With one exception, all these graptolites are dendroid forms which lived under the same conditions as the associated benthonic forms and have therefore the same correlation value as these. Their occurrence is but local and they are for this reason not apt to gain importance as zone markers.

The solitary species of Monograptus exhibits such extreme reduction in size and development that one cannot help but doubt its graptolitic nature altogether on seeing it, but may well infer in view of its stratigraphic position that it is a last gerontic form.

Finally the *Carboniferous rocks* of Missouri have in Dictyonema blairi Gurley also given evidence of the persistence of that extremely long-lived "genus" into Carboniferous time.

7 Note on the continuity of the formation of graptolitiferous beds in the same area and its bearing on certain paleogeographic problems

We have seen passing before our mental vision in the preceding chapter and the corresponding one of part 1 of the *Graptolites of New York* a continuous procession of graptolite zones beginning with the closing stage of the Cambric and continuing, apparently without interruption, to the closing stages of the Champlainic. This fact of the immensely long persistence of the same marine facies in one area is certainly a remarkable phenomenon which becomes the more marvelous when it is taken into account that this area is relatively small, all the graptolite zones being restricted to the slate belt, or the Levis channel, with the exception of the last two which pass beyond its western boundary, at the same time losing their character as typical graptolite shales; and further when it is considered what a variety of rocks were in the same interval deposited in the epicontinental American sea, and even in the adjoining and parallel Chazy basin. To attain a proper valuation of the bearing of this phenomenon on the paleogeography of the region it becomes necessary to investigate whether this continuity of like conditions in the slate belt is but the result of accidental coincidence or the expression of a general principle.

With this end in view we will consider the relative lengths of deposition in the other well known graptolite regions, remarking at the outset that the

persistence of deposition of graptolitiferous shale no doubt exists in the whole Levis basin from New York to the mouth of the St Lawrence.

Remaining for the first on this continent we find that the shales of the novaculite region of Arkansas also indicate a remarkably long persistence of like conditions, the graptolite zones there denoting deposition from the third Deepkill zone (end of Beekmantown or Chazy) to middle Trenton, or if the occurrences in the adjoining Indian Territory are taken in account, even to the end of the Champlainic. A like long interval is indicated by the few graptolites hitherto collected in Nevada.

On the other side of the Pacific we find again in southeast Australia the Champlainic represented by nothing but graptolite shales which in a continuous series range from the very bottom of that system (first Deepkill zone) to at least our Normanskill zone, corresponding to the whole interval from the beginning of the Beekmantown to middle Trenton time, but probably as indicated by the presence of Dicellograptus anceps, the index form of the last Champlainic graptolite zone in Europe, extend to the very end of the Champlainic, or even into the Siluric (Diplograptus palmeus).

Still more striking is the long persistence of the deposition of graptolite shale in certain regions of Europe. In southwest Scotland and the adjoining Lake District of England an immense deposition of shales has taken place, which in this little extensive area in the Skiddaw, Glenkiln and Moffat (Hartfell and Birkhill shale) series have afforded a system of graptolite zones equivalent not only to the entire Champlainic (Ordovicic) from its very beginning, but also, to the Lower and Middle Siluric, or to the time interval from the base of our Beekmantown to the beginning of our Salina age.

This same striking phenomenon repeats itself in Scania where in the lower, middle and upper graptolite shales of the Champlainic and the Rastrites and Cyrtograptus shales of the Siluric we meet an enormous development of graptolite shales but little interrupted by bands of limestone, that in time again extends from the base of the Champlainic to the middle of the Siluric.

Likewise the Ardennes in Belgium and northeastern France have furnished a series of graptolite zones beginning with the Upper Cambric Dictyonema shale and leading up to the end of the Middle Siluric. Smaller series which, however, are still remarkably long when compared with those of the other facies, are formed by graptolite shales in the Bretagne, Wales, the Normandy, Bohemia etc.

The broad proposition can therefore be made that *graptolite shales*, as a rule, *are deposited in the same region for longer intervals than most other fossiliferous rocks;* or in other words, that the conditions producing the deposition of graptolite shales tend *to persist longer in the same region than those producing most other facies.* The explanation for this fact can be found only in the assumption that the regions of this shaly sedimentation were more distant from the ever changing conditions of the higher litoral zones than those of the other contemporary facies, i. e. were in deeper water. This conclusion of the place of origin of the graptolite shales is in full agreement with Lapworth's view that the graptolite shales represent a zone between the agitated bottom, where coarser sediments are deposited, and the dead water of the deep sea, with that of Barrois [1892, p.174] that the graptolite shales were deposited at depths corresponding to those in which the radiolarian ooze is found[1] and with the writer's conception of the mode of existence of the graptolites set forth in Memoir 7 [p.509]. We have there concluded that true graptolites were pelagic, the Axonolipa essentially pseudoplanktonic and the Axonophora holoplanktonic in their mode of life and that the latter from their structure must have preferred the deeper and quieter regions of the open sea.[2]

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[1] The distinguished French author bases his inference mainly on the great amount of authigene silica (60%) in the typical graptolite shale, and especially on the intercalation in them of phtanites which contain radiolarians and diatoms [Cayeux, Ann. Soc. Géol. du Nord, 1891].

[2] During the progress of this discussion the writer has been well aware of certain evidence apparently conflicting with the view of the continuance of deeper water conditions in the northern part of the Appalachian geosyncline. This consists of the observation of the presence of intraformational conglomerates, as that described by the writer from Ryse-

If these conclusions are correct, the paleogeographic importance of the graptolite shales consists as mentioned before in the fact that they, in contrast to the majority of the other clastic rocks with their imbedded mollusk faunas, mark the presence of deeper basins of relatively long continuity.

We will now proceed to show how the view of the long persistence of these deeper basins of the principal graptolite regions falls nicely in line with certain paleogeographic principles enunciated in the last decade. We refer especially to Suess's conception of the relation of the Canadian and

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dorph hill near Albany, and of grit beds; and of the claim advanced by Dale of an unconformity between the Beekmantown and Trenton beds by the absence of the Chazy, which assertion in its turn has obviously led to the inference, by Ulrich and Schuchert, of a draining of the Levis basin in Chazy time.

Professor Dale in his excellent exposé of the geological cycles through which the slate belt has passed [1899, p.298] says of the Lower Cambric sediments: "The frequent alternation of fine and coarse sediments, and of these with calcareous ones, and the occurence of conglomerates indicate changing conditions. There was deep and shallow water, quiet water and rapid currents, occasional exposure of the sea bottom to wave action and then its submergence owing to minor oscillations of the earth crust," and states of the Champlainic: "The Lower Cambrian sediments are followed by the grits, red and green shales and slates of the Ordovician. The same alternation of coarse and fine sediments continues." We agree with Dale that occasional ridges — minor oscillations that were prenuncial of the more general orogenic movement that followed at the end of Champlainic time — were raised at times, causing in part the intercalations of coarser clastic rocks. Similar cases are recorded from the larger geosynclines of Europe, and Haug has pointed out that the first step in the formation of folds on the place of a geosyncline is the rising of a median anticline. It is in this connection not to be overlooked that with a raising of an anticline, as a rule, the formation of deeper depressions on both sides goes hand in hand; and if we consider the small thickness of the conglomerate bands (10–12 feet), their obvious local distribution, and the general and great prevalence of the fine grained shales and slates over the grits and conglomerates we cannot avoid the inference that the total lithologic aspect of the rocks remains that of deeper water deposits notwithstanding these intercalations. If Dale asks [p.297]: "Why should the Ordovician sediments thin out at the west? . . . Were the Ordovician sediments originally thinner on the slate belt, **i. e.** was it an area of deeper water and, therefore, of less sedimentation, or, as previously suggested, was the slate belt a land surface submerged but here and there, with deeper water

Baltic shields to the growth of the continents and Haug's view on the relations of the geosynclines and continental areas, advanced in his highly suggestive paper: "Les géosynclinaux et les aires continentales, contribution à l'étude des transgressions et des régressions marines" [Paris, 1900].

We will begin with the consideration of the views of the last mentioned author. Professor Haug first brings forward accumulative proof that the deposits of the geosynclines were not formed in shallow water as Hall, the originator of the conception of the geosyncline, and some other American

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east of it?" we would in answer use the fact of the greater thinness of the sediments in the slate belt as compared with the regions to the east and west to infer that because these thinner beds are graptolite shales, the dwindling of the deposition in the geosyncline can point only to deeper water and corresponding less sedimentation and not to a but partly submerged land surface. As the grit consists largely of angular grains of quartz and feldspar and scales of muscovite, and the conglomerate bands of pebbles of very different age (Lower Cambric, Chazy, Lowville, Black River and lower Trenton in the Rysedorph hill conglomerate), it is more than probable that these deposits are due to the presence of powerful shifting currents (oceanic, tidal and coastal) which at times carried some of the material far out into the deeper basins, conditions that are well known from the other geosynclines.

In regard to the supposed unconformity in the slate belt at the end of the Beekmantown time, it is stated by Dale [1904, p.49]: "There was also an emergence at the close of Beekmantown time, for the Hudson lies in places immediately upon the Beekmantown, the Chazy being absent. The full thickness of this formation in the lake region is estimated at 890 feet. Mr Ruedemann's doubtful determination of Chazy graptolites in a 40-foot outcrop at the Deepkill cannot suffice to substantiate the presence of a formation representing such a lapse of time as is implied in the deposition of 890 feet of limestone." Professor Dale's arguments for the absence of the Chazy formation in the Levis basin, viz, the absence of the Chazy limestone between the Beekmantown and Trenton shales [*see ibid*, p.33] and the insufficiency of the third Deepkill zone to represent a time interval corresponding to the deposition of 890 feet of limestone, are not convincing to us for the following reasons: It can not be expected that the Chazy stage should be alone represented by a limestone in a series of rocks, where all other stages are represented by graptolite shales, but it should be *a priori* assumed that if present, the Chazy would also appear as a graptolite zone. The succession of the graptolite zones in the slate belt is now thus that it well compares in completeness with that observed in Europe, and that it is apparent that no

authors have claimed, but that they originated in deeper waters as especially argued by Suess, who calls them "pelagic" and Neumayr, who has considered them as "abyssal." Using Renevier's term "zone bathyale" for the zone intermediate between the "zone néritique" (shallow water) and the abyssal zone, Haug asserts that it is the deposits of this zone which consist of terrigenous muds and especially of the blue muds rich in organic matter and sulfids; and further that it is the deposits of this zone that are laid down

important zone is lacking, a fact which can be also inferred from the distinct and close genetic relationship of the succeeding faunas. The third Deepkill zone (the supposed Chazy equivalent) is bound to the underlying Deepkill zones of Beekmantown age by the presence of common forms and the survival of some Phyllograpti and Tetagrapti and especially by the existence of an intermediate subzone (Ashhill beds of Mount Moreno, *see* Memoir 7, p.499); and it is equally closely connected with the following Normanskill shale by the Diplograpti and the Climacograpti and, in fact, lies at Mount Moreno in close proximity to that zone as pointed out before by the writer [*ibid.* p.499, footnote]. Undoubtedly, further study will afford still more transitional zones. If then the graptolite zones in themselves give all evidence of representing a continuous series, they must also comprise the time equivalent of the Chazy formation.

The discrepancy in thickness between the graptolite zone and the Chazy limestone of the Champlain basin is quite proportional to that between the Beekmantown graptolite zones and the Beekmantown dolomites. To the Beekmantown shale, Mr Dale [1904, p.33] assigns 50 feet as a minimum and the present writer's estimate of 200 to 300 feet as a maximum and the Beekmantown dolomite measures 1800 feet. There exists hence no essential difference between the proportion of the Beekmantown shales and dolomites and that of the 40 feet of Chazy shale and the 800 feet of Chazy limestone. Furthermore, it is completely in line with the conception of the graptolite shales as deeper water deposits and Dale's observation of the smaller thickness of the whole system of rocks in the slate belt. Dale assigns (1899) to the whole mass of Champlainic slates only a thickness of 1000 to 1200 feet (1200 to 2500 ? in 1904 to the Hudson formation), while the Beekmantown dolomite alone measures 1800 feet according to Brainerd and Seely, right on the other side of the Quebec barrier in the Champlain basin.

It could be urged that since the Chazy beds in the Champlain region do not reach as far south as their supposed graptolitiferous correlative in the Levis channel, the latter must be of different age, but the conclusion of the persistently deeper water in the Levis basin, derived from its graptolite faunas, would naturally as a corollary also imply a further southern extension of the sea in this channel during Chazy time.

in the geosynclines. As such deposits are named the graptolite shales, the Posidonomya shales, the Dentalium clays, and the argillaceous and calcareous Ammonite shales and compact or nodulous Ammonite limestones, etc. The absence of organic life over vast regions on the argillaceous bottom of the "zone bathyale" is also a feature well illustrated by the barrenness of the greater part of our graptolite shales and the remarkable absence of other fossils in these beds.

As to the relation of the depth of the sea and the constancy of the deposition, Mr Haug states [p.624]:

A une certaine profondeur, des oscillations qui maintiendront le fond dans les limites de la zone bathyale n'amèneront aucune modification dans la nature des sédiments déposés, aussi les dépôts n'offriront-ils que de faibles variations dans le sens vertical et cela sur des épaisseurs souvent très considérables. C'est là encore une raison de plus pour attribuer à un grand nombre de géosynclinaux une profondeur relativement grande.

This general independence of the deposition from oscillations in the northern Appalachian geosyncline during Champlainic time is strikingly illustrated by a comparison of the series of graptolite shales in the Levis basin with that of the varying synchronous rocks deposited to the west of it.

The Appalachian trough is the classic example from which Hall's conception of a geosyncline took its origin. But in size, importance and length of existence it is not comparable with the geosynclines which encircle the Pacific and Indian oceans and which according to Haug's lucid discussions persisted as the mobile parts of the earth crust through all geologic ages, giving rise to the large mountain systems of the earth. But it seems to us that this smaller geosyncline gains greater importance and interest if considered as a member of a system of very ancient geosynclines which stand in some relation to the Baltic and Canadian shields. If we turn again to the principal Champlainic graptolite regions of Europe, viz, Scotland, Wales, Bretagne and Scania, we find that they are the sites of the very ancient geosynclines which surround the "Baltic shield" of Europe and have given origin to the ancient mountain systems of Great Britain and the Bretagne. In America we find the graptolite zones in the Appalachian

geosyncline in the east, and in the great geosyncline of the Rocky mountain region in the west (Nevada, British Columbia) and connecting the two, the occurrences in Arkansas and Indian Territory, which may well be considered as the northern edge of a long curved depression that in the south connected the Appalachian geosyncline with the great Rocky mountain geosyncline without, however, leading there to like extensive folding. This great semicircular depression bounded the vast platform that stretched southward from the Canadian shield and was flooded in Champlainic time by a shallower epicontinental sea.

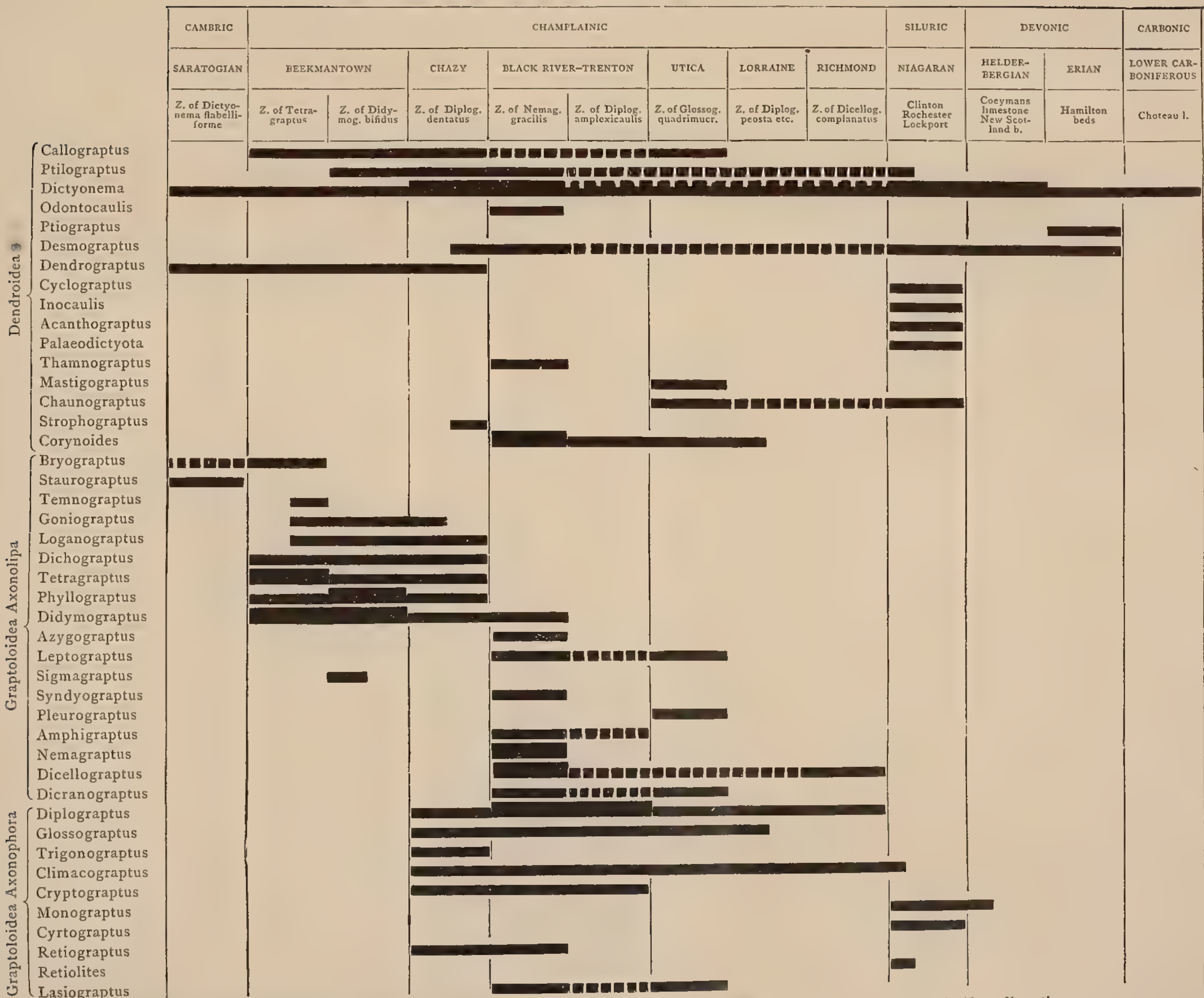
Synoptic view of the range of the graptolite genera of the United States[1]

The synoptic table following serves (1) to illustrate most concisely the hemeras and the relative vitality of the orders and genera of our graptolites, (2) to suggest phylogenetic connections and (3) to show more distinctly the relations of the zones than long verbal explanations could do. We will for these reasons consider the ranges of the genera separately from the discussions of the zones and briefly note the points illustrated by the table.

In surveying the relative length of the biotic lines — which by the way are here made to begin and terminate bluntly at the zonal boundaries, principally to hide our ignorance as to the actual points of origination and termination of the genera within the zones — one will at once notice the disproportionate lengths of the biotic lines of several of the Dendroidea. Foremost of these is Dictyonema which extends from the Cambric to the Carbonic and apparently possesses two culminating periods (according to number of species), one in the early Champlainic and one in the Niagaran-Lower Devonic time. It is to be assumed that the appearance of these two culminating periods is a deception due to our as yet incomplete knowledge of the Dendroid faunas. It has been suggested that the long persistence of the genus Dictyonema is not so much a sign of its extreme

[1] An extension of this synoptic view on the forms occurring in Canada, which would complete the list for the whole of North America, would according to our present knowledge, hardly necessitate any changes beyond the addition of a few Dendroid genera from the Niagaran of Hamilton, Ontario.

SYNOPTIC TABLE OF THE RANGE OF THE GRAPTOLITE GENERA OF THE UNITED STATES[1]



[1]A more detailed table of the range of the genera of the Cambric and Lower Champlainic is found in Memoir 7, page 508. A dotted line signifies a discontinuous range.

vitality but of our failure to distinguish the different groups of possibly different internal structure but like external appearance. The same could be said of Desmograptus.

In contrast to these long-lived genera stands a group of Niagaran Dendroid genera (Cyclograptus, Inocaulis, Acanthograptus, Cactograptus, Palaeodictyota) of very short range. The whole range of these groups is probably not known, especially may they be older than is indicated by their observed range. This is suggested by the appearance of a form (Dendrograptus ? succulentus) in the third Deepkill zone that has many characters indicating its ancestral relations to Inocaulis, Acanthograptus and Palaeodictyota.

The genera of the Axonolipa are nearly all quite short-lived. The synoptic table clearly brings out the fact that they appear in two different successive outbursts. The first in early Beekmantown time (Zone of Tetagraptus) with the genera Temnograptus, Goniograptus, Loganograptus, Dichograptus, Tetragraptus, Phyllograptus and Didymograptus. Only the last-named of these genera extends into Mesochamplainic or Mohawkian time. But there another group of genera appears mainly forming the families Leptograptidae and Dicranograptidae, viz, Azygograptus, Leptograptus, Syndyograptus, Pleurograptus, Amphigraptus, Nemagraptus, Dicellograptus and Dicranograptus. Nearly all of these (except Azygograptus) show their progress beyond the Dichograptidae of the Paleochamplainic by the sigmoid curvature of their thecae. A genus (Sigmagraptus) of the same group standing in front of them in the preceding column of the table suggests already by its position the ancestral relations demonstrated by its form. Few of these genera lived in Neochamplainic time and none passed beyond the end of the Champlainic.

Proceeding down the table, we come again to a pronounced projection of the genera into an earlier zone in the Axonophora, where the genera Diplograptus, Glossograptus, Trigonograptus, Climacograptus, Cryptograptus and Retiograptus appear together, ushering in the new climacteric period of graptolites (Diplograptidae) in the Trenton. The beginning of

their biotic lines shows distinctly that they can not have been derived from the Dicranograptidae, as formerly suggested, nor from any Leptograptidae but that they probably go straight back to the Dichograptidae as indicated by other morphologic considerations [*see* under phylogenetic notes].

Finally a small group of genera (Monograptus, Cyrtolites) are our faint indications of the third grand outburst of graptolitic types, that of the Monograptidae in the Siluric.

The synoptic table also brings out several facts of the zonal distribution of the genera which are otherwise not quite so apparent. The most interesting of these is the generic composition of the third Deepkill zone, which has in common with the preceding Beekmantown zones the Dichograptidae, viz, Goniograptus, Loganograptus, Dichograptus, Tetragraptus, Phyllograptus, Didymograptus and with the succeeding (Normanskill) zone the Axonophora: Diplograptus, Glossograptus, Climacograptus, Cryptograptus, Retiograptus, while the second fauna of the Axonolipa, typically represented by the family Leptograptidae, which appears in the Normanskill shale is here absent. It is mainly on account of the peculiar intermingling of the disappearing genera of the first fauna of the Axonolipa with the new appearing genera of the Axonophora that this zone has been correlated with the Chazy formation.

The Mesochamplainic, beginning with the zone of Nemagraptus gracilis, is in the table seen to be characterized by the appearance of the second fauna of the Axonolipa of the leptograptid and dicranograptid type, with the genera Leptograptus, Syndyograptus, Pleurograptus, Amphigraptus, Nemagraptus, Dicellograptus, Dicranograptus, and the continuance of the Diplograptidae of the Chazy, as well as the appearance of the peculiar genus Lasiograptus while of the first fauna, that of the Dichograptidae, only Didymograptus is left. It survives, however, in various descendants as set forth in another place.

The table further brings out the interesting observation that, after the Normanskill shale (zone of Nemagraptus gracilis), the Mesochamplainic is unproductive of new genera, and still more so the Neochamplainic. The old

genera are simply gradually dying out, only a few of the most vigorous holding their ground and finally producing the new genera characteristic of the Siluric. Thus the Utica shale only produces the peculiar and rare Dendroid genera Mastigograptus and Chaunograptus, the single Axonolipous genus Pleurograptus that is monotypic and very short-lived and no new Axonophora at all. The succeeding Champlainic zones have not furnished any new genera and hardly any new species.

The Devonic has with the exception of a distinctly paracmic species of Monograptus afforded but Dendroidea and in Ptiograptus still produced a most striking new generic type of that order. Thus the Dendroidea are not only the first appearing graptolites but also the last to leave the field, one form of Dictyonema even persisting in America into Carboniferous time.

ADDITIONAL NOTES ON MORPHOLOGY

a Notes on morphology of spines

In a study of the later graptolite faunas of the Champlainic one can not fail to notice a great increase of spinose forms in comparison to the earlier faunas. The contrast becomes still more marked when the fauna of the third Deepkill zone, where the biserrate forms appear first and which in its general aspect is more similar to the Upper than to the Lower Champlainic faunas, is counted with the former. The spines are in their morphology, the place and time of their appearance and the amount of their development of manifold interest, mainly in regard to the phylogeny of the larger groups, since several authors, most clearly Beecher, have shown that they are in all living beings most sensitive indicators of the degree of development attained by the species. A separate discussion of the numerous spinose forms described in this paper promises, for this reason, to yield a few facts of interest. Besides, such procedure will prevent repetition in the systematic part of the paper.

We shall see that the spines of graptolites arise from different causes, at different stages of the development of the genera, at different places and are of different morphologic character. At the same time they furnish

instructive illustrations of several biogenetic principles evolved in the study of other animal classes; and they also give important evidence of the beginning of a division of labor in the graptolite colony asserted before by the writer.

Beecher in his philosophical paper "On the Origin and Significance of Spines"[1] distinguishes a number of causes of the formation of spines. These factors of spine genesis are divided in constructive and destructive agencies. The former may arise from external stimuli or intrinsically from growth force. The latter extrinsically from external restraint or intrinsically from a deficiency of growth force.

The first group, which is the most important for our consideration, offers five aspects under which the production and growth of spines may be considered. Three of these, viz, growth (1) in response to stimuli from the environment acting on the most exposed parts; (2) as extreme results of progressive differentiation of ornaments; (3) secondarily as a means of defense and offense, it is here pertinent to consider; the two others (sexual and mimetic influences) being excluded from consideration by the low organization and our insufficient knowledge of the graptolites.

There is no doubt that the spines of the great majority of the graptolites have grown from the first mentioned cause and it is properly stated by Beecher that "the apertural spines on some of the graptolites are on the most exposed portions of the hydrothecae, as in Monograptus spinigerus, Dicranograptus nicholsoni, Retiograptus tentaculatus and Graptolithus quadrimucronatus." A comparison of the location of the spines in some of the genera will serve to establish this point. In the great majority of the species the spines are formed at the apertures of the thecae, which project beyond the body of the rhabdosome. They are there placed either singly on the outer side of the aperture, appearing as extensions of the "denticle" or paired and projecting from either side of the aperture as in Glossograptus quad-

[1] Beecher, C. E. Origin and Significance of Spines. A Study in Evolution. Am. Jour. Sci. v. 6. 1898.

rimucronatus [*see* text fig. 1]. In the genera Dicellograptus and Dicranograptus the thecae possess a sigmoid curvature and the apertures are situated in well defined excavations. The most exposed point of the theca is hence the protruding buckle in the middle of the free portion of the ventral margin [*see* text fig. 2], and there the spine is always found. An analogous position of the spines is found in graptolites belonging to an entirely different order Thus in excellently preserved specimens of Climacograptus putillus [*see* text fig. 3] it is seen that at the point where the theca turns somewhat abruptly from an oblique direction to one subparallel to the axis, a small (mesial) mucro is developed and this is certainly the most prominent place of the outer wall of the theca.

Fig. 1 Glossograptus quadrimucronatus var. cornutus nov. Fragment of rhabdosome. x 5

This principle is still more clearly illustrated by the distribution of the spines on the rhabdosome. It is found that in most forms the spines are restricted either to the mouth of the sicula (virgella and other accompanying spines as in Cryptograptus, text figure 7) or to the first two thecae, wherever by recurving of the branches — in the Dichograptidae — or by the growth of the thecae in proximal direction the sicular end is placed farthest from the center of the colony. In genera like Bryograptus, Dichograptus, Goniograptus, Tetragraptus, Didymograptus [*see* Mem. 7, pl. 5, 6, 7] where the sicula comes to lie close to the primary disk, neither the sicula nor any of the first thecae will as a rule develop any spines. Where, however, in any species of these genera the branches of the rhabdosome make an abrupt turn to attain the ascending direction discussed in Memoir 7, the most convex part of the bent branch will develop spines. This is for instance shown

Fig. 3 Climacograptus putillus (Hall). Fragment of sicular end. x 5

Fig. 2 Dicranograptus nicholsoni var. parvangulus Gurley. Distal portion of rhabdosome. x 5

in Tetragraptus fruticosus [*see* Mem. 7, text fig. 11, *also ibid.* pl. 10]. In those groups of Tetragraptus and Didymograptus, in which the recurving of the branches takes place close to the sicula, as in Tetragraptus similis [*ibid.* text fig. 58] the sicula and first thecae become spinose. Frequently the difference in aspect between these first, strongly spinose thecae and the later ones is strongly marked [Leptograptus flaccidus var. spinifer]. In several species of Didymograptus (D. subtenuis) and Nemagraptus (N. exilis Lapworth, text figure 4) only the sicula and one theca on either side are armed with spines, but these are found exactly where the change in direction of the branches takes

Fig. 4 Nemagraptus exilis var. linearis nov. Shows spines of primary thecae. x 5 Fig. 5 Diplograptus angustifolius Hall. Sicular end showing character of spines. x 7 Fig. 6 Glossograptus quadrimucronatus var. cornutus nov. Sicular end showing lateral spines. x 7 Fig. 7 Cryptograptus tricornis (Carruthers). Aperture of sicula showing four spines. x 7

place and thereby a part of the branch is projected. Among the Diplograpti either the virgella alone grows out needlelike, or it is accompanied by the opposite spine of the sicula and two more powerful spines grow from the first two thecae; this even in forms where the later thecae are wholly unarmed, as in Diplograptus angustifolius [*see* text fig. 5] and D. foliaceus [*see* text fig. 286]. In some varieties, as in D. foliaceus var. calcaratus and D. trifidus Gurley these spurs attain such relatively great size that they become the most striking feature of the colony [*see* text fig. 295]. In Glossograptus quadrimucronatus the thecal apertures are each protected by a pair of lateral spines, but the

first two thecae develop one gigantic spur each that is placed on the ventral or outer side of the theca [*see* text fig. 6]. In Cryptograptus tricornis [*see* text fig. 7] there are four spines developed from the apertural ring of the sicula.

All of these above cited observations point to causal connection between the spines and the exposure to external stimuli of the places where they grow. The form and strength of the spines further leave no doubt that they have secondarily become adapted to organs of defense and thereby attained considerable importance. In the case of Climacograptus bicornis, which will be treated at the end of this chapter, a further development and adaptation to an entirely different function has taken place.

Besides the cases of spiniferous forms cited thus far, there are others which can not be explained by the influence of external stimuli and still others which present features that point to the agency of additional factors. Most prominent among these are the cases of strong spinosity in the last dwarfed phylogerontic mutations of otherwise nonspinose forms, already noted in part 1 in the descriptions of Tetragraptus pygmaeus, Didymograptus caduceus var. nanus and Phyllograptus anna mut. ultimus. Here also belongs Didymograptus nanus, which is figured as a spinose form by Perner and others. In regard to Didymograptus caduceus mut. nanus I had stated [pt 1, p.698] that "its constantly smaller size, its wider proximal part, the abrupt narrowing of the branches, the smaller size and closer arrangement of the thecae and the spinose processes of the lower ends of the apertural margins indicate a concentration of the entire development of the rhabdosomes into smaller space and shorter time, denoting the paracmic condition of the mutation." All of these cited dwarfed forms appear at the very end of their "phyla" and are undoubtedly the last weak survivals of their races.

The supposition that they might have degenerated by unfavorable physical conditions or "restraint of environment" is contradicted by their position at the end of the race and still more by the fact that in the

same horizon other genera and species are in a most flourishing condition. The restraint must, therefore, have been intrinsic and I believe, we can not err in concluding that the vital power of these races had failed and the deficiency of vital power had first led to the appearance of these pathologic looking mutations and finally to the extinction of the races. We have hence here cases of racial old age and of *spinosity as an expression of waning vital power*.

As a third group of spines in graptolites, we have to consider those which appear on other than the most exposed places and on the rhabdosomes of forms clearly not astophylogerontic. The best examples known to me are Tetragraptus acanthonotus Gurley, Didymograptus spinosus Ruedemann and the genus Glossograptus. The first and second of these occupy unique positions within their respective "genera" by differing from all other congeners in possessing besides "acute denticles," or apertural mucronal extensions, spines all along the dorsal side of the branches [*see* Mem. 7, text fig. 85]. In Tetragr. acanthonotus these spines are so distributed that they correspond to every second theca and in Did. spinosus one is placed opposite each theca; and in Glossograptus not only the apertural margins are provided with spines on either side, but there are also series of spines running down the middle of the lateral sides, the latter corresponding to the dorsal spines of the two other species mentioned. There is nothing in Tetragr. acanthonotus to indicate that it could have been a phylogerontic form, it appears with the earliest Tetragrapti in the lowest Quebec zone and is ruggedly developed. It is somewhat different with Didymograptus spinosus, which appears after the culmination of the genus Didymograptus and by its small size and somewhat rapid expansion has a contracted aspect, suggestive of a phylogerontic condition. Yet for another reason we will discuss it in this connection. Glossograptus appears fully armed with spines in the third Deepkill zone together with the first Diplograpti and continues in this condition through the next formations to its extinction. This is clearly not a case of phyloparaplasis, for the genus gives by the number of

its species and the latter by the size and the great number of their individuals sufficient proof of undiminished vital power. The spine growth begins already vigorously with the sicula, which has at least four spines [*see* text fig. 8], two of which are continued in the series on the lateral faces, the others in the apertural spines. For these reasons I believe that we have here an unmistakable instance of the factor which Beecher has denoted as *production of spines by repetition.* In regard to this agency he says:

> When from any cause, the forces of nutrition are directed toward spine production, and when the direct results are accomplished in the reciprocal formation of one or more spines, there is often an apparent inductive influence or impulse given to growth toward the further production or repetition of spines. This may result in the formation of compound spines, or a group of spines, or even produce a generally spinous condition.

There is little doubt that the first impulse in the case of Glossograptus was given by external stimuli. These resulted in the formation of spines around the apertures of the thecae, a condition that was carried back to the sicula and thence spread over the lateral sides of the rhabdosomes.[1] The same is true, we surmise, in the cases of Tetragraptus acanthonotus and Didymograptus spinosus but since the sicula of neither of the two has been observed, there is no direct evidence bearing on this problem.

Fig. 8 Glossograptus ciliatus Emmons. Young colony. x 5

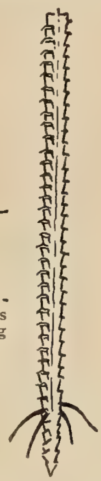


Fig. 9 Glossograptus quadrimucronatus (Hall). Copy from Lapworth. Nat. size

An interesting case of inceptive or intermittent repetition is that observed in the variety of Glossograptus quadrimucronatus occurring according to Lapworth in the Irish graptolite shales, where large spurs like those of the aperture of the sicula appear again upon the lateral sides opposite the fourth or fifth theca [*see* text fig. 9]. The points of their appearance are not nearly as exposed as the sicular extremity of the rhabdosome or the apertures of the thecae, and not more than any other

[1] It is to be noted in this connection that the forms which have apertural spines only, possess only one or two sicular spines, as Dipl. foliaceus.

parts of the long, broad, flat lateral sides. They express for this reason, quite distinctly an intrinsic tendency to a repetition of the lateral apertural spines.

Another group of spines in our material is represented by those observed in Lasiograptus mucronatus, bimucronatus and whitfieldi. In these the apertural spines are primarily the bearers of extrathecal structures, consisting of a network of fibers etc., but they indicate by their rigid stout form that secondarily they also acquired a defensive function [*see* plate 30]. In Memoir 7 (p.518, 539) it has been claimed by the writer that the extensive perforations and the final reticulation of the peridermal walls in the Retioloidea are expressions of a strong tendency to lighten the rhabdosome, resulting from the adoption of a planktonic mode of life. In Lasiograptus [*see postea*] the extrathecal fibrous structures are either the result of progressive differentiation of former spines, as generally assumed, or, as suggested by Törnquist [Silj. grapt. I, t. 2, p.27] the distal parts of thecae that have been dissolved into meshes. If the latter inference is correct, the spines of Lasiograptus are not homologous to any of those of the preceding groups. In that case they result from what Beecher has termed "*restraint of environment causing suppression of structures.*" The environment, i. e. the open sea, was not favorable to the development of strong peridermal walls and led to a gradual suppression of this structure, the suppression in this case beginning at the apertural end of the theca and proceeding in proximal direction, leaving the spines as principal vestiges of the process.

Fig. 10 Rastrites linnaei Barrande. Copy from Perner. x 4
Fig. 11 Monograptus sp. Copy from Perner. x 4

Entirely different again in origin and character is the spinose appearance of certain species of Monograptus and Rastrites [*see* text fig. 10, 11], which is especially well expressed in several of Perner's accurate drawings [*see his* pl. 13, fig. 27, 28, 29; pl. 12, fig. 17, 25, 30; pl. 37 *et al*]. In these the spines are not integumental excrescences but the thecae themselves assume the form of spines, the aper-

ture being reduced to a small pore at the apex of the spine. These spiniform thecae, though obviously adapted to defensive purposes, are not comparable to the spines of other graptolites here discussed, and apparently have no such bearing upon the phylogeny of the class as the spines. There are also thecae in early species of Dictyonema, Dendrograptus and other genera that by their acute form may have themselves assumed the function of defensive spines.

Having traced the origin of the spines in the forms here under investigation, we will now turn to the bearing of the time of their appearance on the question of the stage of development of the spinose forms. Considering the whole class of graptolites, the appearance not until Trenton time of the great majority of the spinose forms corroborates the observation made in regard to other classes, as the Trilobites, Brachiopods and Ammonites, viz, that the greatest development of spinose organisms occurs just after the culmination of a group, and, as this period clearly represents the beginning of the decline of the vitality of the group, the spines are to be taken as the visible evidence of this decadence. According to Beecher the appearance of spines indicates the paracme of a class.

If we compare, however, the appearance of spines in the various phyla of the graptolites, it will be seen that it does there by no means begin everywhere either in the same astophyletic stage or correspond in its principal development to the paracme of the race.

In Tetragraptus pygmaeus, Didymograptus caduceus var. nanus and Phyllograptus anna mut. ultimus spinosity does not appear until just before extinction or in the last astophylogerontic substage. Perhaps this phenomenon can be accounted for by the fact that the races to which these forms belong, die out before the acme of the whole class is reached. They may then illustrate the principle established by Hyatt that gerontic characters appear first in the ontogenetic and phylogenetic history of a group in the last stage and are progressively pushed into earlier stages. On the other hand we have the very early spinose, though thus far isolated Tetragraptus acanthonotus.

If we compare the size and frequency of the individuals of a number of graptolites in which spinosity is more or less developed, as Diplograptus foliaceus, Glossograptus quadrimucronatus, Tetragraptus fruticosus and Climacograptus bicornis with that of their congeners, we can not avoid the inference that they are the most stately and in three of the four also the commonest and most widely distributed species which certainly must mark the acmic development and the period of highest vitality of their races. In Climacogratus bicornis this is combined with such a great variety of modifications, all occurring in the same horizon, that I have here described them separately and inferred that they indicate the period of "zooic maximum" of this stock [*see* under b].

In the genera Glossograptus, Dicranograptus and Dicellograptus, spinose forms appear directly at the outset, in the latter two associated with nonspinose forms. Here the short life of the genera or their very small vertical range has to be taken into account and inferred that their rapid development was followed by so rapid a decline that ascending and descending forms could be separated only by most refined stratigraphic work. I have no doubt, however, that the latter would show an increase of spinose forms in the upper subzones of the Trenton beds.

The distribution of spines on the rhabdosomes of the graptolites is lastly of interest on account of its bearing on our conception of the graptolite colony and of the sicula. The writer has in former papers contended that there are features in the graptolite colonies — such as beginning division of labor, developing symmetry of arrangement, presence of common organs — which indicate that the colonies had begun to progress to a concentration of functions, leading to an approach of the colony to a functional individual, if not to a morphological one. The distribution and development of spines furnishes some further interesting clues along this line of investigation not noted in the former publications. These are the facts that in certain forms as in Glossograptus quadrimucronatus, Diplograptus foliaceus and Climacograptus bicornis either the first two thecae may be provided with spines different in position

from the other spines as in the first named species, or they alone may bear spines, and that these spines may grow to such extreme size that the thecae are thickened into spine bases [*see* text fig. 6] similarly as those of Goniograptus thureaui are into stems, losing thereby their normal functions. It is in these cases obvious that the first two thecae have, by division of labor, been assigned to the task of protecting the most exposed part of the colony. In some mutations the virgella or sicular spine also grows out to great size and the sicula shares in the defensive work.

Also the distribution of the spines on the first six or eight thecae of the rhabdosome in Dicellograptus while, as stated before, originally due to the exposure of these thecae to the strongest external stimuli, is in some degree indicative of a differentiation of the thecae.

The appearance of the spines on the first thecae, which has been just discussed, seems to contradict the former statement of the writer that "the rhabdosomes in toto and their parts, the branches, seem to pass through stages which suggest phylogenetically preceding forms," for the spines which as new features ought to be expected first on the last thecae or the astogerontic part of the colony appear in the first thecae of the colony. But it must not be forgotten that these spines are not so much an expression of waning vital power and originate intrinsically, as the result of external stimuli at the places where the impact of the latter is most frequently felt. They are hence rather of the character of new acquisitions by external physical conditions than of internal physiological changes and in this regard only in a general way indicative of the paracmic condition of the class but not of their special phylum.

Similar observations could be made in regard to the spinose character of the sicula. There are forms where the sicula alone is spinose. The most notable of these are Cryptograptus antennarius and Cryptograptus tricornis. In the latter the sicula is even furnished with four long spines [*see* text fig. 7]. From this it can be concluded that the distal part of the sicula, which is provided with growth lines, is not to be considered as an embryo sheath, for the embryonic sub-

stage is throughout the animal kingdom uniformly free from spines. But it is in line with this fact that the thin proximal part of the sicula, which does not possess growth lines [*see* Mem. 7, text fig. 2], never possesses any traces of spines and that especially in such genera as Diplograptus, where the virgella extends into the wall of the sicula, it apparently does not enter this "embryonic" part of the sicula.

The distal part of the sicula appears for this and other reasons to hold in regard to the proximal part the position of a larval form to the embryo, and it certainly holds this position in regard to the whole colony, representing its astonepionic growth stage.

In Cryptograptus tricornis this larval stage alone is formidably armed with four long needlelike spines, while the succeeding thecae are free from spines, and the profusely occurring, spinose siculae remind one of the long spinose larvae or zoëae of crabs. The spinosity of the latter is due to "cannibalistic selection" according to Verrill, the larvae preying upon each other and therefore needing this protection. While the tenants of the siculae of Cryptograptus can hardly be considered as having been of sufficiently high organization to be able of such cannibalism, the fact is clear that they, like the siculae of many other forms, were subject to attacks which led to a development of spines not repeated in the succeeding thecae and that these spines partake more of the character of coenogenetic features, and are not directly connected with the phylogenetic history of the genus, a view that also agrees with their presence on the oldest species of the genus. In this case the development of spines could not be held to have been pushed back by tachygenesis into the larval stage.

b Note on terminal spines of Climacograptus bicornis

Perhaps the most striking objects among the Normanskill graptolites, especially those from Glenmont near Albany, are the appendages of the sicular end in Climacograptus bicornis Hall. They present at first sight an almost bewildering variety of forms and all possible modifications of a single pattern. They all occur in one and the same horizon

and a little further study shows that even the most extreme forms are connected by an infinite number of transitional stages. It thus becomes apparent that we have here one compact phylogenetic group of no more than specific rank which, however, with a sudden outburst of variability develops along various lines, some of which diverge widely enough to have been designated as different varieties.

In the succeeding Utica formation the species, or a mutation of it, persists, but the wealth of appendical forms has disappeared, and the ontogenetically earliest and phylogenetically oldest plain, double-spined form alone survives.

I have here arranged a number of the most characteristic forms from the Normanskill shale on plate A to bring out synoptically the probable lines of development of the varieties. The elements of these modifications are the two spines, arising from the outer walls of the first two thecae, the virgella or principal spine of the sicula and the alate extensions of the spines.

The simplest stage is the *bicornis stage,* occupying the lowest tier of the plate. In this only the two lateral or thecal spines are developed. The young of all the other varieties pass through this stage and the form shown by most of the young and the Climacograpti of the preceding horizon is to be considered as the most primitive. This is the one represented at the base of the plate, with two slightly curved, widely diverging thin spines. These appendages then begin to vary by (1) the degree of their divergence and (2) their curvature. They become either straight as in the lines g and e, recurving as in f or curving inward and becoming semilunar as in the other lines a–d.

The degree of divergence of the spines may be influenced by the direction of compression and some of the apparent modification is hence due to this cause. Since with the exception of the line a, in which the prongs have been subparallel, the angle of divergence has not been given any importance and the appendages would naturally tend to settle on this flat side, the direction of compression is evidently a factor that can be here neglected.

The simple needlelike spurs of the earliest bicornis stage show a tendency to develop wings on their back. In most specimens these wings grow most rapidly at the base of the spines, as in the lines a, b, d, e, f of the plate, whereby in the inward curving varieties a crescent form arises [*see* 9, 12], in the straight spined forms appendages similar to mackerel-tails [13] and in the recurving forms appendages reminding one of lumbermen's hooks [14].

By continued growth of the wings the group of forms is originated, which has been designated as Climacograptus bicornis var. peltifer [tier II of plate A]. A glance at the plate shows that here again all of the bicornis varieties occur, namely forms with crescent-shaped spines (b), with straight diverging spines (e), straight horizontal spines (g) and recurving spines (f). The oddest looking of these are perhaps those with straight horizontal spines and a triangular shield [19]. Among the peltate forms with crescent-shaped spines two groups become again quite distinct, namely those in which the spines continue to grow and to protrude as needlelike points beyond the wings (as in line d, 16) and those in which the growth of the wings overtakes that of the spines [24].

But not in all of the bicornis forms does the wing grow strongest at the base of the spines, in some it appears first in the middle of the spine as a small outgrowth (as in 5) and continues to grow strongest there and to taper towards both the base and point of the spine (as in 10 and 11). These individuals form a distinct group by themselves. By continued growth baglike wings are formed, like those represented in tier III [29 and 30; *see also* enlargements in text fig. 14, 15]. In this group which I have here designated as var. signum in allusion to the similarity of the extreme forms to the standards of Roman legions an independent outgrowth of two semicircular wings, forming together a disk, is found. This formation is best shown in text figure 14. From its preservation partly below and partly above the other wing it appears that this disk partly overlapped the other older one and had a slightly oblique position, though also growing from the lateral face of the rhabdosome.

Plate A

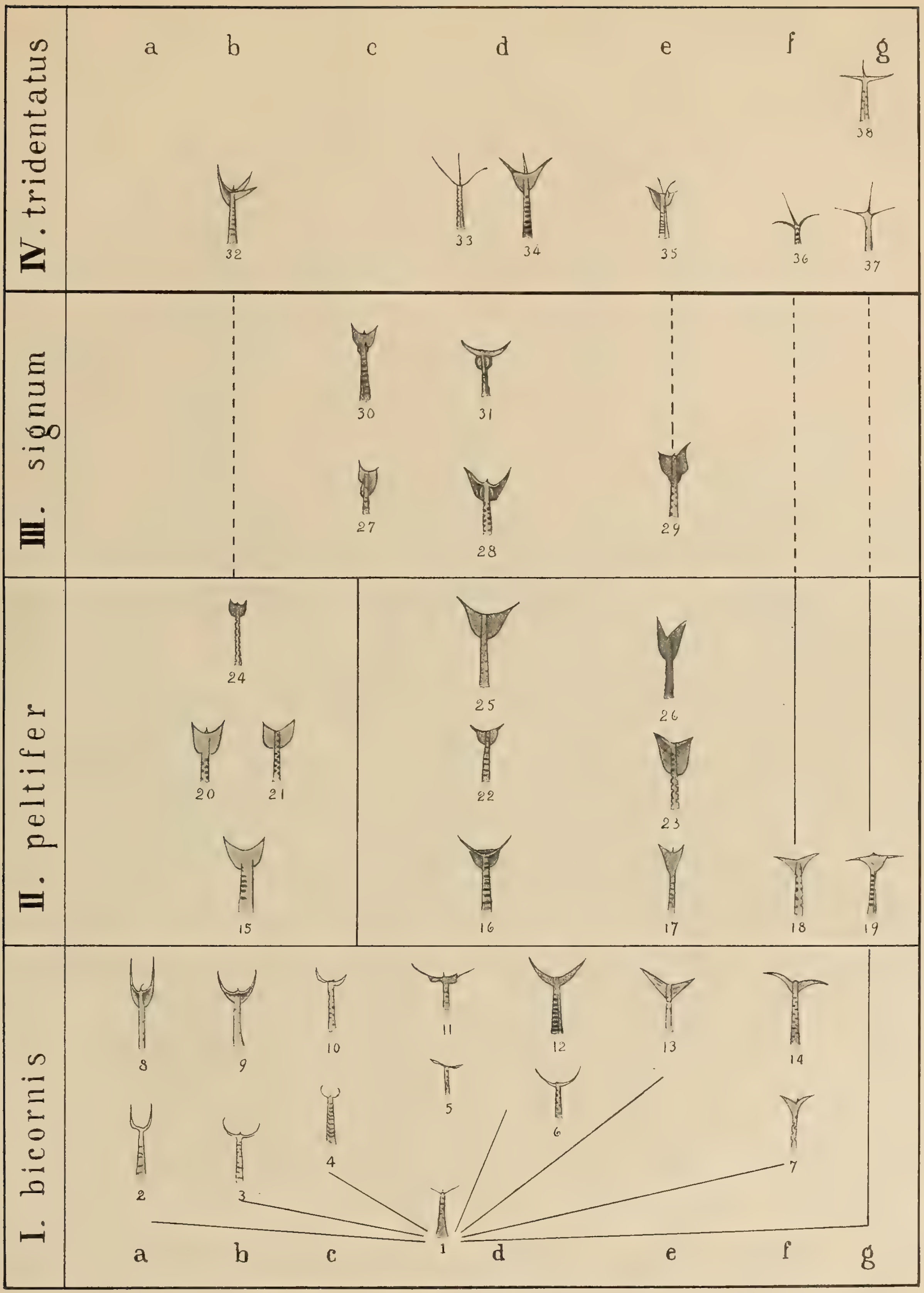


Table showing varieties of Climacograptus bicormis

Various forms are here possible according to the relative development of the two groups of wings. In text figure 15 the wings on the spines are but little developed, but the later disk-forming wings the more; in others as in text figure 13 the earlier outgrowths of the spines are so strong that in the compressed stage they cover the later disk more or less.

A fourth group (tridentatus Lapworth) originates from the stronger development of the virgella or sicular spine besides the two lateral

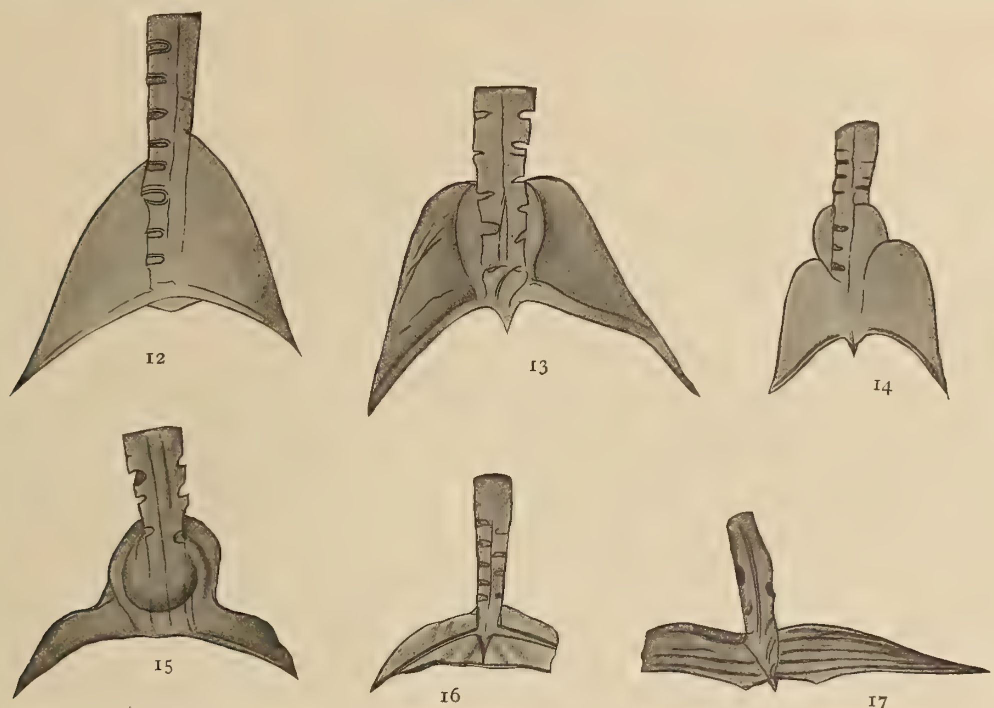


Fig. 12–17 Climacograptus bicornis Hall. Sicular ends showing the lateral spines and "wings." x 5

spines. It will be noticed that many of the bicornis forms, as 3, 6, 8, 9, 11, show already a short, blunt virgella. But in some forms it takes a spurt and grows out way beyond the lateral spurs, as in 36 and 37. In a few specimens as in 32 it even develops its own wing, while in others [33] it remains fine and hairlike like the lateral spines. This tridentatus variety rarely may become combined with the peltifer form as in 34 and no doubt also with the signum form. The lateral spurs

may be in this group again straight horizontal, crescent or recurving, exactly as in the other groups and sometimes even the lappet of the sicula, lying opposite the virgella and seen as a blunt mucro in 36, may develop into a long spine, and thus a four spined variety be formed as that represented in figure 35.

In describing the appendages I have used the terms wings and disks thereby assuming that they are flat bodies of the character of alate extensions. Since they are known only in the compressed stage, it is just as possible that they were cuplike bodies or hemispheres, or at least bags in the var. signum. The following facts appear to argue against the latter possibility. The wings are frequently unequally developed, on both sides of the rhabdosome, as in text figure 12, hence independent of each other and not combining into a cuplike body or hemisphere. Their suspension from two spines does not suggest such bodies, nor does the presence of the semicircular disks alongside the wings in var. signum indicate any great expansion of the appendages. Still there have been noticed in several specimens lappets protruding from behind the wings as in text figure 12 and in others, as text figure 17, the wings are traversed by horizontal folds. In text figure 16 the test extends to the tip of the virgella and exhibits a marginal thickening.

Frech [1897, 553] has cited Climacograptus bicornis as a clear case of the development of a rudder aiding in a kind of vertical swimming or floating movement and has argued that physae or pneumatophores could impossibly be placed in the center and also at the periphery of a synrhabdosome. We do not see any facts combating this view and many in support of it. Some of the latter are that in the formation of the wings there is an obvious endeavor to secure a large surface and their form therefore reminds more of the tail fins of fish than of anything else; they are clearly but auxiliary organs, for they do not develop in early age, nor in all varieties, the variety tridentatus and the Utica mutation lacking them. It is further suggestive in this connection that the size of the appendage is approximately proportional to the size of the rhabdosome, that hence the

largest and most protruding rhabdosomes of the entire stock where the rudder would be most effective, bear the largest disks, while the young rhabdosomes, which are more or less hidden in the crowd of rhabdosomes, do not possess any.

Only separate rhabdosomes having been found, the question could be raised whether not one and the same synrhabdosome might have borne the various modifications of the appendages, characteristic of peltifer, signum and tridentatus in such places, where they would have been most effective, as for instance the tridentatus type of appendages at the upper periphery of the bundle of rhabdosomes. In that case, of course, they could not be considered as indicating varieties of the species but would demonstrate a rather remarkable division of functions. The crucial test for the solution of this question lies in the finding of synrhabdosomes with the various appendages. Meanwhile, it may be stated that on the slabs bearing the broken rhabdosomes those with like or similar appendages are so much more frequently associated as to suggest that each synrhabdosome bore appendages of but one kind.

c Influence of spines on development of retioloid structure in the periderm

There exists, in the writer's opinion, a distinct relation, which it is proper to point out in this place, between the development of the spines and that of the stronger ledges of the second peridermal layer. In spineless diplograptids as D. foliaceus there is not even in strongly macerated specimens, a trace of a system of retioloid fibers or ledges observable beneath the continuous periderm. In Glossograptus quadrimucronatus, which has rather short, paired apertural spines, a system of mouth and parietal ledges is present which, however, is so weakly developed in comparison to the stronger main layer of the periderm that it is but rarely observed. In Glossograptus ciliatus where the spines are very prominent, the peridermal layer is still present, but the retioloid layer has become so strong that in macerated specimens, it is found to form a continuous network with four longitudinal main-ledges besides the nemacaulus. The periderms of Lasiograptus mucronatus, L. bimu-

cronatus and Glossograptus whitfieldi are here shown to possess a like composition. This leaves in the division of Diplograptus with spines but Diplograptus aculeatus Lapworth and D. insectiformis Nicholson.[1]

In regard to D. (Idiograptus) aculeatus, Lapworth [1880, p.171] makes the following significant remarks: "The test is of great tenuity, and is frequently invisible; an outline only of the angles of the fossil is preserved in strong *chitinous threads.* The zigzag septal line seems to be formed of a single thread of this nature, apparently of no greater thickness than that which outlines the hydrothecae." D. insectiformis is a very small form and therefore not favorable for the observation of the discussed structure, especially if the latter is but little developed and the outer layer rather strong.

In surveying the evidence, given by the species here cited, we feel that we can venture the general proposition that *the spinose forms of "Diplograptus" possess as a rule a layer of retioloid meshes* and as a corollary that the *development of this layer of meshes and ledges is roughly proportional to that of the spines.*

From this proposition it can be deduced that the spines are casually connected with the principal parts of the retioloid layer, i. e. with the main ledges, and secondarily also with the entire meshwork. It is to be assumed that the formation of spines required basal braces or supports which grew out like roots from the bases of the spines into the surrounding peridermal tissue, and formed the ledges by uniting for mutual support. It is in this connection to be noted that the spines in the species cited not only proceed from the main ledges, but also lie in the points of intersection of the ledges. The formation of the main ledges would easily induce that of further connecting bars and thus lead to a retioloid structure, especially since the combined formation of the spines and of the layer of meshes will

[1] D. uplandicus Wiman, which is cited by Frech among the spinose diplograptids, does not properly belong there, since it only possesses the lateral spines of the first two thecae, like nearly all other diplograptids and climacograptids.

naturally increase materially the weight of the rhabdosome and thus call for the reduction of the continuous periderm.

It is not claimed that all retioloid structures have originated from the formation of spines, for some have none. Spinosity is considered as but one of the factors of the production of the Retioloidea. Another one has been pointed out in Memoir 7, page 518, where the extensive perforation of the periderm in retioloid forms has been ascribed to a general tendency to lighten the rhabdosomes induced by the assumption of holo- and pseudo-planktonic modes of life in the later graptolites.

The question is also here left open whether the retioloid layer in the spinose forms is lying below the continuous layer of the periderm or is only a constituent part of the same in form of a strengthening framework, which finally alone remains. The latter supposition is perhaps nearer the truth. It is indicated by Wiman's observation that in Gothograptus nassa the meshes are sometimes connected by fragments of a membrane, and Wiman directly terms the meshes the strengthening supports of the middle layer. On the other hand, this retioloid framework does nowhere in the spinous forms here discussed project on the surface of the rhabdosome, which is smooth; and it must therefore, if a part of the middle layer of the periderm, have extended inward and formed, so to say, an inner substratum. For this reason we have here conveniently termed it an inner portion of the middle layer of the periderm.

d Dilatations ("vesicles") of nemacaulus in Diplograptus, Climacograptus and Cryptograptus

In several species of Climacograptus and Cryptograptus described in this memoir, the nemacaulus exhibits peculiar expansions which in at least two species attain such prominence that at times they must have been of considerable functional importance.[1]

[1] These expansions are strictly to be separated from those found at the other, sicular end, of the rhabdosome in such forms as Climacograptus bicornis var. peltifer. The latter originate from the virgella and the lateral spines and the former from the stem or nemacaulus. Nor do they seem to have had like functions.

The first to observe a dilatation of the stem in a diplograptid was Barrande in Diplograptus palmeus [1850, p.60]. He made the following observations (translated):

Fig. 18 Diplograptus vesiculosus Nicholson. Copy from Lapworth. Nat. size

Most frequently the naked axis (nemacaulus) undergoes a torsion which one recognizes by a pronounced strangulation, beyond which one sees a large dilatation. In several individuals we observe that this abnormal enlargement manifests itself in the place of the last thecae of the adult part, i. e. in the region where we have supposed the successive withering and shedding of the oldest zooids to have taken place. Finally, various specimens show the naked axis separating in two or four branches, which gradually widen toward the extremity.

In 1869 Nicholson described a Scottish form as D. vesiculosus on account of "a long, fusiform, ovate or cylindrical vesicular dilatation" of the nemacaulus, "which is bordered by strong filiform margins." He states that this species always possesses the vesicle, while in others as D. pristis and D. palmeus, it is but sometimes seen. The "vesicles" of D. vesiculosus seem indeed to be quite constant, for they have again been observed as a normal feature by Lapworth in West Scotland [1876, pl. 2, fig. 41] and in Ireland [1877, p.133] and the same author has described in C. scalaris var. tubuliferus from West Scotland and Ireland, a form whose nemacaulus is stated to expand "into a long flattened plate or vesicle." In Nicholson's monograph of British Graptolites a like expansion is figured of Diplograptus folium [*see* text fig. 19].

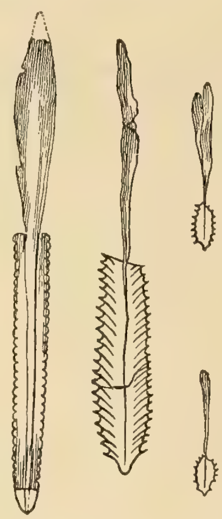


Fig. 19 Group of Diplograptidae with dilatations of nemacaulus. Copy from Nicholson

Gurley has observed similar swellings of the nemacaulus in Climacograptus parvus Hall, which was described by him as C. phyllophorus in allusion to these appendages; and also in C. caelatus. In regard to the former it is stated [1896, p.77]:

The chief interest in the species lies in the "disk." This has the form

of and strikingly resembles an elliptic pinnate-veined leaflet, a resemblance hightened by the likeness of the virgula to the midrib, and the presence of several obscure, obliquely directed fibers running from it on either side outwards and proximalwards. An exactly similar but differently-shaped appendage is constant in *C. caelatus* from Nevada, and probably it is equally constant in *C. phyllophorus*, though here the longer, more slender virgula is more frequently broken. This appendage appears to differ from that found in such species as *Diplograpsus vesiculosus* Nicholson in being accurately bilaterally symmetrical, and in being plainly traversed by and not forming (as apparently is the case in *D. vesiculosus*) a dilatation of the virgula.

Fig. 20 Climacograptus parvus Hall. Rhabdosome with dilatation. Copy from Gurley

We copy here his figure in illustration of his views.

In specimens of *Climacograptus caelatus* from the Beekmantown shales at Summit, Nevada, Gurley has also observed a dilatation of the nemacaulus of which he says [1896, p.76]:

This body is an obtriangulate-cordate leaflet, bilaterally symmetrical, and traversed medianly by the virgula. Some appearances suggest that it may possibly consist of two superposed elliptic leaflets. It is sometimes at a distance from, sometimes close to, or in actual contact with the proximal ("distal") end of the polypary. From the (apparent) dilatations of the virgula seen in *D. vesiculosus* Nicholson, *D. palmeus* (Barrande) and *D. trifidus* Gurley, it differs markedly in its distinct bilateral symmetry, and flat leaflike appearance. This "disk" is present in a large proportion of the specimens.

Fig. 21 Climacograptus caelatus Lapworth. Copies of Gurley's figures showing the "disk." x 2

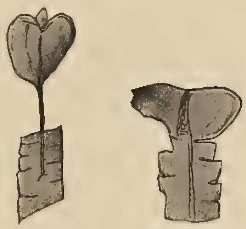


Fig. 22 Climacograptus caelatus Lapworth. Camera enlargements of the dilatations. x 5

Gurley did not figure these disks in the preliminary publication from which this note is taken, but we have found in his manuscript some figures of the same made under his supervision, which are reproduced here [text fig. 21]; and we add some camera drawings of our own to further illustrate certain features [text fig. 22].

A further form with a dilated nemacaulus was made known by Elles

[1898, p.518] in Diplograptus appendiculatus Törnq. ms, in regard to which it is stated:

From the upper end (of the rhabdosome) proceeds the vesicle, inside of which the virgula can quite well be detected [*see* text fig. 23].

The present writer observed a "cucumber-shaped" expansion of the nemacaulus [1904, p.722, pl. 16, fig. 2, 3] in Diplograptus laxus (lateral view of Cryptograptus antennarius, *see* under Cryptogr.).

Fig. 23 Diplograptus appendiculatus Törnquist manuscript. Copy from Elles

I have before me, besides Gurley's material of the vesicles of Climacograptus phyllophorus and C. caelatus, a very large collection of finely preserved vesicles of the former in all stages of development from the Normanskill shale at Glenmont, and those of Cryptograptus antennarius and tricornis. This material, it seems to me, permits some observations of interest on account of its bearing on the structure and function of the "vesicles."

We have noted in the foregoing quotations that the English authors have unhesitatingly termed these appendages "vesicles" without, however, entering upon a discussion of their possible function. Gurley on the other hand has pointed to the bilateral symmetrical form and flat leaflike appearance of the appendages in the two specimens of Climacograptus and designated them as "disks."

The features observable in our specimens, to which we would direct attention, and the resulting inferences, are:

1 The "virgula" passes distinctly through the appendages, as Elles has pointed out in regard to Diplograptus appendiculatus. The large appendages of the species of Climacograptus here noted show the same feature, and frequently the rod extends beyond the expansion and ends bluntly with a distinct break [*see* text fig. 24]. They are further found in all stages of development from narrow lanceolate

Fig. 24 Climacograptus parvus Hall. Dilatation with virgula in median line. x 5

25

26

30

29

28

27

Fig. 25, 26 Climacograptus parvus Hall. Figure 25 is a rhabdosome with dilatation of nemacaulus showing overlapping of parts. Figure 26 is a dilatation showing partial separation of parts. x 5

Fig. 27, 28 Climacograptus parvus Hall. Nemacauli with numerous small dilatations. x 5

Fig. 29, 30 Corynoides calicularis Nicholson. Nemacauli with small dilatations. x 5

bodies to broad ovate or subcircular ones in mature rhabdosomes, independently from the growth-stages of the latter. From these facts we infer that the expansions were a secondary development, and not homologous to the "primary disk" from which the siculae and colonies of most graptolites are suspended; but perhaps in some measure corresponding to the "central disk" of certain Dichograptidae.

2 Certain observations suggest that the appendages were indeed bags or vesicles and not flat "disks" or "wings." These are the distinct overlapping of some parts over others in the compressed state [text fig. 25], the presence of longitudinal folds and the collapsed appearance of some of the appendages and the composition of the test of two superposed layers which is indicated by a partial separation of the layers, apparently from a bursting of the body [*see* text fig. 26] and the breaking up of the vesicle into three or four broad widening longitudinal bands [*see* Barrande's figure of D. palmeus] or into two equal overlapping halves as in Nicholson's specimen of Diplograptus folium [*see* text fig. 19].

3 Two possible functions of these vesicles have been tentatively suggested, viz, their connection with the former presence of older thecae by Barrande [*see* above] and their possible service as pneumatophores in cases of accidental separation of the rhabdosomes from the colony [*see* Mem. 7, p.519]. Barrande's view is based on a wrong conception of the rhabdosome, the latter being now known to have grown in the direction of the vesicle. The writer had stated in the afore mentioned place that "the vesiclelike expansions of the nemacaulus and of the distal appendages of certain species of Diplograptus are plausibly explained as organs which assisted in floating the synrhabdosomes and eventually protected the broken-off rhabdosomes from sinking." In the same volume [p.652] a like origin is assigned to the broad nema of Tetragraptus fruticosus.

As observations in favor of the latter view could be cited the apparent vesicular shape of the appendage, its development in mature rhabdosomes only, where the weight is greatest. Perhaps in such species as Diplograptus vesiculosus, where they are said to be always present, they

formed habitually while the rhabdosome was still a part of the synrhabdosome. In others, however, as Climacograptus parvus, one may observe great numbers of associated rhabdosomes without any trace of vesicles, while in another layer the vesicles may be very frequent.

The bed at Glenmont, which contains them in such great numbers, is remarkable for the association of this Climacograptus with an equally great number of rhabdosomes of Lasiograptus mucronatus. The latter is a notably light form on account of its very thin peridermal walls; and its association with the apparently thick walled rhabdosomes of Climacograptus parvus indicates that the weight of the latter had been balanced to such an extent that they could drift and settle at the same rate as those of the Lasiograptus. The frequent absence of vesicles in long-stemmed rhabdosomes of Climacograptus parvus and the presence of all growth stages of the vesicle in mature rhabdosomes would suggest that these vesicles did not form until a necessity for their formation arose, i. e. when the nemacaulus had been broken and the rhabdosome had become separated from the center of the synrhabdosome.

There are several other facts leading to the same inference; as the position of the vesicle at no regular distance from the rhabdosome, but always close to the broken end of the nemacaulus. This is especially noticeable in C. caelatus where sometimes the vesicle forms plump against the growing end of the rhabdosome [*see* text fig. 22], thereby hindering or even preventing further growth. In some specimens the entire nemacaulus becomes covered with small vesicles [text fig. 28], as if there had been a strong endeavor or stimulus to the quick production of numerous supporting vesicles. Numerous such small vesicular appendages have been observed on many individuals in the nemacauli of several other forms, as Glossograptus and Corynoides calicularis [text fig. 29, 30]. The formation of one large vesicle may here have been dissolved into that of many smaller ones.

4 Finally, the appendages of Climacograptus parvus permit the observation of some structural details of the nemacaulus.

The axis or "virgula" of the Axonophora has been currently considered as a solid body until Wiman [1895] observed that it is a hollow continuation of the sicula in Diplograptus and the present writer [1895, pl. 2, fig. 6] finding a specimen of Glossograptus quadrimucronatus in which a solid rod (Wiman's virgula, which forms in the wall of the sicula) had been forced out of the tube during the process of compression, concluded that the solid axis of the sicular wall extended into the proximal tube.

Fig. 31, 32 Glossograptus ciliatus Emmons. Dilatations of nemacaulus. x 5

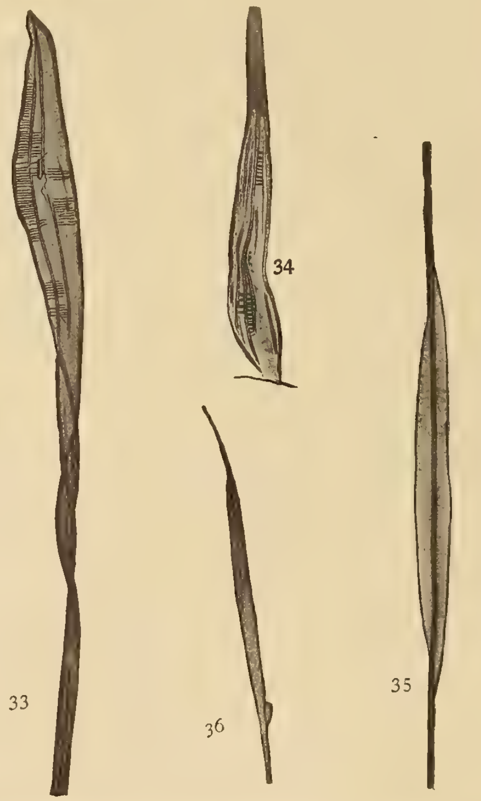


Fig. 33-36 Climacograptus parvus Hall. Dilatations of nemacaulus. x 5

A contribution was published last month by A. Schepotieff (1905, p.79 ff) in which it is shown, by means of thin sections, that the "virgula" of Monograptus priodon consists of a hollow tube with a central solid rod [*see* text fig. 38, 39]; and thereby verified the writer's observation in regard to Glossogr. quadrimucronatus. The question arises

now of the relation of both the inflations and their central axes to the nemacaulus and virgula. I think it is *a priori* probable that the vesicles are local inflations of the outer tube (nemacaulus) and that the axes seen to pass through them in D. appendiculatus and the two species of Climacograptus are the central solid rod or virgula proper. An inspection of the appendages of C. parvus leaves indeed no doubt of the truth of this assertion. It is seen that the axis of the vesicles is much narrower and less in substance than the nemacaulus bearing the vesicles. Text figures 27 and 31 distinctly illustrate this difference in width. In 27 it is not more than one fourth of the nemacaulus and in 31 about one half. The central axis while containing less carbonaceous substance than the nemacaulus, is still distinctly thicker in most specimens than the walls of the vesicles. All these facts must be viewed as supporting the inferences of the presence of a solid axis within the nemacaulus and the origin of the vesicles from inflations of the nemacaulus.

In that case it is also more probable that the appendages were real vesicles or inflations than that they formed flat disks or wings of the nemacaulus walls. If they were alate expansions one would, where the vesicle has been split through the middle in the breaking of the shale, thereby exposing the virgula [as in text fig. 35], expect to note the boundary of the canal of the nemacaulus against the solid wings but nothing of the kind is observed in the many appendages, and the continuing of the somatic canal into the inflation is everywhere apparent. If the vesicles served as pneumatophores, as has been claimed above, there probably existed a partition between the somatic canal proper and the gas receptacles and it is possible that a further separation of the tissues of the wall had taken place which can not be discerned in compressed material.

In macerated vesicles of Climacograptus parvus the walls are invariably dissolved into strings of fine hairlike fibers, extending longitudinally in the direction of the nemacaulus and apparently anastomosing in long intervals, thereby forming very long and narrow meshes [*see* text fig. 34], whose interspaces are filled by thinner carbonaceous films. This structure would

exactly correspond to the meshwork of growth lines observed by Wiman in the apical or embryonic part of the sicula of a Diplograptus [*see* Mem. 7, text fig. 2]. Since the nemacaulus is a direct proximal continuation of this part of the sicula, it is to be expected that it is identical in wall structure with the latter and the observation of such structure in the walls of the vesicles can be considered as a further argument for the view that the vesicles are inflations of the wall of the nemacaulus.

The "several obscure, obliquely directed fibers running from it (the virgula) on either side outwards and proximalwards" observed by Gurley [1896, p.77, *see* text fig. 20] in C. parvus are fragments of the same structure, but there is no organic connection between the virgula and the fibers and the aspect similar to the venation of a leaf is merely accidental in Gurley's type.

e **Note on the extension of the virgula into the nemacaulus in the Axonophora**

Fig. 37 Glossograptus quadrimucronatus (Hall). Young rhabdosome showing nemacaulus and virgula. Copy from Ruedemann

The writer has in part 1 [p.487] proposed to distinguish sharply between the hollow, tubular process extending from the proximal end of the sicula to the primary disk in both the Axonolipa and Axonophora, and the solid rod forming in the wall of the sicula in the Axonophora; by applying to the former the terms *nema* (in the Axonolipa) and *nemacaulus* (in the Axonophora) and restricting the use of the term *virgula* (applied by some authors to the tube) to the solid rod. Of the latter, the writer had already in 1895 claimed that it extends into the nemacaulus and thus continues into the rhabdosome. This assertion was mainly based on the observation of a specimen [*see* text fig. 37] of Glossograptus quadrimucronatus in which obviously the solid virgula had been forced out of the nemacaulus by a bending of the latter This view has lately been verified by two groups of observations. First, A. Schepotieff [1905, p.79 ff] has been able to demonstrate by thin sections the presence of a solid rod in the nemacaulus of species of Mono-

graptus [*see* text fig. 38, 39] and thereon mainly placed his claim of the closer relationship between the graptolites and Rhabdopleura; and then the writer has been able to observe the presence of a continuous rod in the vesicular swellings of the nemacaulus in Climacograptus and Glossograptus [*see* fig. 35]. The inference of the presence in all the Axonophora (as conceived by the present writer, i. e. with exclusion of the Dicranograptidae) of this solid rod in the nemacaulus, is hence hardly to be doubted; and in its presence would have to be seen a most important distinction between the Axonolipa and Axonophora.

Schepotieff's sections show this remarkable rod which he terms the "innere Stab der Virgula" to lie free in the center of the nemacaulus, originally held there by tissue not any more preserved. As it partly forms in

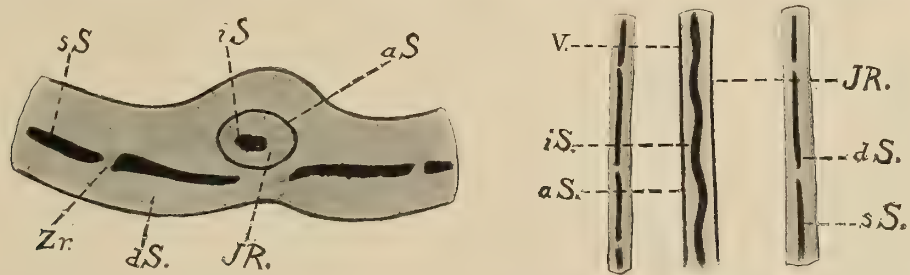


Fig. 38, 39 Monograptus priodon Bronn. Transverse [fig. 38] and longitudinal [fig. 39] sections showing the nemacaulus (a S) with included virgula (i S). Copies from Schebotieff

the wall of the sicula, it probably had also its origin in the wall of the nemacaulus on the same side, we surmise, as in the sicula, and became only secondarily free in the nemacaulus.

The bearing of the presence of this supporting rod in the nemacaulus on our conception of the mode of life of the Axonophora has already been discussed by the writer in part 1 [p.517], and the purpose of this note is merely to point to the fact of the recent verification of its actual existence and to the inference of its general presence in the Axonophora.

f Sections of Climacograptus typicalis and Diplograptus amplexicaulis

It has been observed in Climacograptus typicalis [*see* description] and Diplograptus amplexi caulis [*see* descr.] that the cross-

sections of the rhabdosomes are concavo-convex and that this feature is due to the growing of the thecae out of the axial plane of the rhabdosome toward one side (the reverse side) in such a way that in a view of that side [*see* text fig. 40] the apertures of both rows of the thecae are seen and in the opposite view none. In surveying a large number of specimens of both species, one will find that not all rhabdosomes are equally concavo-convex in their section; that while some are extremely so, others are merely flat on the concave side and but slightly convex on the other, and that correspondingly the thecae are but little turned toward the reverse side.

If one looks for an explanation of this peculiar growth direction of the thecae, only one possibility would seem to suggest itself, viz, that this lateral growth is a further modification of the complete reversion in the growth direction of the rhabdosome in the Axonolipa in the effort to attain an ascending position of the thecae. It is hardly to be doubted that these two species grew in synrhabdosomes such as have been found of other Diplograptidae and that probably their synrhabdosomes bore as many or more rhabdosomes as have been observed in Diplograptus foliaceus. In that case numerous rhabdosomes would in the crowded radiating bundle not find sufficient space to assume vertical or nearly vertical positions that would give to the thecae their most advantageous (ascending) direction, but would have to approach a horizontal position. It is in the latter rhabdosomes that the thecae would naturally tend to grow out of the axial plane to assume again an upward direction. The facts that the thecae of both rows grew towards the same side and that there exist obvious differences in the amount of this flexion of the thecae in different rhabdosomes can be readily explained by this assumption.

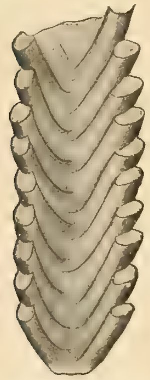


Fig. 40 Diplograptus amplexicaulis (Hall). Portion of rhabdosome which is preserved in relief. x 5

It is further to be noted that in D. foliaceus, where the thecae all remain in the axial plane of the rhabdosome, we observe extreme differences in the lengths of the free nemacauli. While in the few synrhab-

dosomes found [*see* pl. 24, fig. 5] nearly all rhabdosomes, — the mature ones included — are closely attached to the center by but very short free nemacauli, the slabs are covered with other, broken-off rhabdosomes with extremely long free nemacauli. This indicates that in that species the different lengths of the nemacauli may have provided space for all new growing rhabdosomes in the desired approximately vertical position, the oldest rhabdosomes keeping ahead of the younger generations by continuous prolongation of their nemacauli.

In the two species here mentioned on account of the concavo-convex sections of their rhabdosomes, none or but very short free nemacauli are observable — a very striking fact in the multitude of specimens of C. typicalis; it is, hence, probable that in these species the older rhabdosomes continued to hug the center of the synrhabdosome, whereby the younger generations were driven to more horizontal positions.

The present writer has always held that the solid rod (virgula) in Diplograptus (and probably in all the other Axonolipa) not only extended through the rhabdosome but also the full length of the nemacaulus. In merely suspended rhabdosomes there would be no need for this strengthening rod, but it is quite in line with the observation here recorded that the virgula should have developed with the necessity of keeping the multiplying rhabdosomes from crowding around the vertical axis of the synrhabdosomes and maintaining them in more or less horizontal positions, a task that grew more difficult as the rhabdosomes became longer and heavier

g Different preservation facies of graptolites (Gurley)[1]

The difference in the aspect of the same species of graptolite in different states of compression and preservation is very great, and the

[1] Professor Lapworth has in his manuscript report on graptolites forwarded to Dr Gurley in 1890 commented upon the great variety of appearances of Diplograptus foliaceus according to the direction of compression, kind of matrix, etc. Dr Gurley has taken up this theme and worked out the various possible aspects and their explanations; and this chapter as bearing on the deceptive appearances of all the Diplograptids here described, is inserted in the general part of the memoir.

effect is much more striking than with any other group of fossils. Not only does a beginner believe upon superficial examination in the specific distinctness of two different preservation facies of the same form but experienced observers have several times, after careful study, committed the same error. The most striking instance of this is Diplograptus foliaceus Murchison, to which many so called species are to be assimilated. The following remarks will have special reference to this species, although more or less applicable to the graptolites generally.

To begin with the *true* characters of a Diplograptid polypary are only seen in the *uncompressed state*, i. e. when the thecae have been filled out with mineral matter so that they do not, upon compression, flatten out to a thin film. In this state D. foliaceus has been long known in America under the name of D. amplexicaulis Hall of the Trenton limestone. Professor Hall's figures and description refer, not to the complete polypary (which apparently he did not possess) but to the impression left upon the limestone after the removal of the complete polypary. Thus in addition to the exact and detailed agreement between such imprints and Professor Hall's figures we have his statement that the fossil forms a thin film upon the rock, and the further fact that neither his figures nor this description could possibly refer to the complete polypary. This preservation facies, which is the usual one in the limestone and becomes common in the shale in proportion as they are calcareous, I shall throughout this paper designate as the *normal facies*. It is so well described in the extract from Professor Lapworth's manuscript report[1] that it requires no further discussion.

Such a polypary may be compressed in several directions. Some one of these preservation facies is the usual condition found in soft shales; and as these are the principal graptolite-bearing beds these fossils are generally seen as flattened films.

A cross-section of a generalized diplograptid polypary may be diagrammatically represented as a rounded oblong. This polypary may undergo compression in three principal ways; viz (1) along the longer diameter, (2) along the shorter diameter and (3) along the diagonal. The first produces an ordinary bilaterally symmetrical view, which I shall name the *direct* facies; the second the "scalariform" facies and the third a facies which may be called the *oblique* facies. The last is well shown by Emmons's D. dissimilaris. A little thought will show that in this form the thecae must *overlap* on one side and *underlap* on the other.

When a form like Diplograptus amplexicaulis imbedded in the soft mud is subjected to compression those parts of the polypary which are least rigidly connected with the common body and virgula suffer the greatest amount of displacement relative thereto. It is evident that this

[1] See under Diplograptus.

portion is the outer ends of the thecae while on the contrary the inner ends of the thecae are supported not only by their proximity to the common body but also by the walls of the (in the direct facies) next subjacent theca. Thus when the shale is split, while, owing to the comparatively firm texture of the common body and virgula, the line of fracture nearly always follows the *surface* of these structures, it usually *cuts through* the thinner thecal walls, and, as the inner angle of the thecal mouth has been pried up into prominence, it suffers the greatest amount of loss of substance, the resulting form being that with acute "denticles" (the remains of the obliquely truncated theca walls) so frequently seen in the Stockport and Normanskill shales.

The facies of D. foliaceus Murchison, is typically displayed in the so called "D. pristis Hall" so abundant in the Black Shales of the Hudson Valley. For this reason I shall term it the *pristoid* facies. As would naturally be inferred from the fact that the normal facies is mainly a result of limestone preservation, while the pristoid facies is mainly a result of shale preservation, intermediate linking facies are by no means common. Still they do occur. Thus in the calcareous Utica shales, just above the Trenton limestone.

D. amplexicaulis may be seen acquiring the characters of D. pristis. Also an occasional specimen is seen scattered among the multitudes of pristoid forms in the collection from Magog, Canada.

Another facies is that exemplified by Dr Emmons's Diplograpsus rugosus. This differs from the preceding only in the fact that, in addition to the oblique truncation of the walls, the furrow bounded posteriorly and vertically by the anterior edges of the walls of the theca next behind (which have been, as shown above, obliquely truncated during the splitting of the shale and which now form a "cliff" the hight of which is the thickness of the two thecal walls pressed into contact) and anteriorally and horizontally by the underlying surface of the upper wall of the theca next in front, remains filled by a thin film of shale which gives to the distal portions of the thecae an appearance of discontinuity from the proximal portions, thus causing them to simulate a theca of a trapezoidal or subrectangular form projecting from the main portion of the polypary approximately at a right angle. This may be called the *rugosus* facies.

The deceptive appearance mentioned above of oblong or trapezoidal thecae projecting directly outward from the polypary is still more markedly displayed in what I shall call the *Climacograptus* facies. In this case, owing to different amounts of compression, of polypary resistance etc., the thecae are still more inclined to the plane of the section and consequently successive pairs are more widely separated, thus permitting the insinuation between them of a thicker film of shale. Owing to their greater inclination

to the section plane the thecae are always cut through giving us the appearance shown by Diplograptus trifidus Gurley.

We thus see that the so called "cell denticles" upon the shapes of which the older writers laid so much stress as bases for specific distinction have at most only a very indirect relation to the actual specific characters. In other words their average constancy is merely a function of the averages of direction of shale-splitting, of compression and of polypary resistance, and we also see that their liability to variety of appearances must be relatively to that of the species itself (i. e. the normal facies) very much greater, being the resultant of the joint action of three variables instead of one.

h Axes of the Dicranograptidae

Frech [1897, p.615] has placed Dicranograptus (with Dicellograptus as a subgenus) in his Order Axonophora and figured a specimen of Dicellograptus divaricatus Hall var. **rigidus** Lapworth [*ibid.* p.620], stating that this possesses an especially strong virgula, the latter being figured as branching at the point of bifurcation of the branches and extending into both branches. While originally accepting the presence of such a virgula in the branches as an established fact, the writer has come, from his observations, to doubt the presence of any axis — either tubular as the nemacaulus or solid as the virgula — in the uniserial branches of the Dicellograptidae.

Fig. 41 Dicranograptus ramosus Hall. Sicular portion of rhabdosome with nema. x 5

There has been observed by the writer a young specimen of Dicranograptus ramosus, in which a nema protrudes from the antisicular extremity of the uncompleted biserial portion [*see* text fig. 41], indicating that the latter grew along this tube, by means of which the sicula was suspended from the primary disk; but there has been found no trace of any nema or virgula in any of the branches in spite of continuous attention to this problem during the study of a great number of specimens. Nor has, as already stated in other places, been anywhere observed the protrusion of a thread beyond the broken antisicular ends of any of the uniserial branches. The direct evidence of our material is hence against the assumption of the presence of axes in the branches.

But even if such axes as depicted by Frech existed in Dicellograptus, they were in no way homologous to those of Climacograptus or Diplograptus, for the virgula of a Diplograptus is initiated in the wall of the sicula and grows in antisicular direction within the nemacaulus. In Dicellograptus, however, the apical end of the sicula lies outside of the branches, and its short, stiff nema can frequently be seen protruding freely into the axillary angle [*see* fig. 42]. It could, hence, not continue into the branches of a Dicellograptus, but may become incorporated, as we have seen above, into the biserial portion of a Dicranograptus. The virgula of a Dicellograptus would, therefore, have to be a new acquisition, different from that of a Climacograptus. As such it could be assumed to be a continuation of a supposed virgula of the sicula in opposite or apertural direction, the virgula dividing into two branches, but the presence of a virgella, which is the legitimate continuation of the virgula in that direction, opposes such assumption.

Fig. 42 Dicellograptus gurleyi Lapworth. Sicular portion of rhabdosome preserved in relief. x 7

There are also phylogenetic considerations militating against the connection of Dicranograptus and Dicellograptus with the Axonophora. There is excellent reason for deriving Dicellograptus from Leptograptus [*see* p.116] and Dicranograptus from Dicellograptus. Leptograptus, however, like all Dichograptidae does not possess any axes (nema and virgula) within its branches, the nema always remaining independent of the branches. The general structure of the rhabdosome has not changed materially in the development of Dicellograptus from Leptograptus, the differential characters lying mainly in the form of the thecae. There is, hence, no reason for the development of axes in Dicellograptus.

The formation of the virgula in the Diplograptidae and Climacograptidae evidently results from several causes, viz, the biserial growth of the rhabdosomes, their suspension from a nemacaulus and the possible function of the former as steering apparatus.

It is in this connection quite interesting to note that where a biserial portion is formed, as in Dicranograptus, this is found to incorporate the

nema of the sicula thereby producing in the Dicranograptidae a homologue of the axis of the Diplograptidae; and this short piece of nema is the only representative of an axis in that group of which we are aware. In basing the reference of Dicranograptus to the Axonophora on this short nema, one would have to consider the whole group of the Dicranograptidae as a transitional one between the Axonolipa and Axonophora or rather, since Dicranograptus appears to become extinct, as a group which has not fully reached the level of the Axonophora.

i On the morphology of the thecae of the Dichograptidae and Dicranograptidae

There occur in the Normanskill shale of Mount Moreno near Hudson pyritized specimens of Dichograptidae and Dicranograptidae which shed some interesting light on the morphology of the thecae and branches. In these specimens the somatic cavities are filled with pyrite while the periderm has either been entirely destroyed or reduced to a mere coloring film. As a result of this favorable preservation, certain features of the interior structure are revealed, no indications of which are detected in external views.

We select here for description specimens of Didymograptus subtenuis and Dicellograptus gurleyi.

Text figures 43 and 44 represent proximal and distal portions of a rhabdosome of the former species. The sicula and primary thecae are not well shown. The internal casts of the proximal part of the branch demonstrate the following morphologic facts. The new theca diverges from the mother theca in its growth direction for a brief period but returns immediately to it thus producing a small cavity just beyond its budding point (best seen in the mature thecae, figure 44). It then adheres to the mother theca as far as the aperture of the latter where it again diverges though but very slightly. This new direction is then retained. It is that of the branch for the length of the remaining part of the theca and becomes thus the factor that produces the gentle curvature of the proximal part of the branch. Without it the branch would remain straight.

It seems hence that there are two or more factors operative in producing the curvature of the branches. One of these is the tendency in the suspended rhabdosome to give the branches a recurving form and thereby to gain for the thecae an ascending direction. This tendency and its phy-

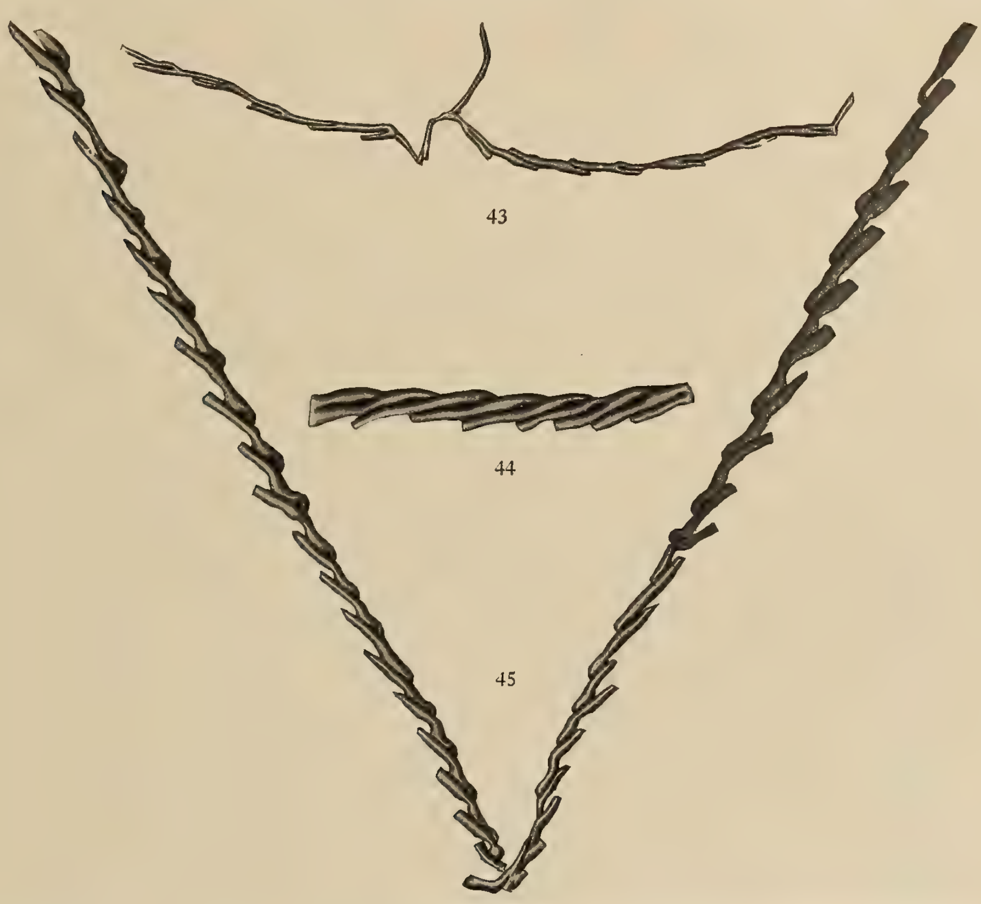


Fig. 43, 44 Didymograptus subtenuis (Hall). Proximal and distal portions of rhabdosomes preserved in relief. x 7

Fig. 45 Dicellograptus gurleyi Lapworth. Rhabdosome preserved in relief. x 7

logenetic aspects have been fully discussed in part 1. Another is the influence, just mentioned, of the aperture of the mother zooid on the growth direction of the daughter zooid.

It is quite probable that in the initial divergence of the young theca an ontogenetic character of some phylogenetic bearing has to be seen, and

that it points to an original dichotomous branching between each two successive thecae, the production of the uniserial branch being only a secondary acquisition, that insures greater strength to the rhabdosomes.

In the Dicranograptidae the change in growth direction is still more complicated by one grade. Text figure 45 shows that the somatic cavity changes its direction three times. At the budding point it diverges from the mother theca but immediately reapproaches it, describing in its growth a small semicircle; then it adheres to the mother until close to the aperture of the latter where it again diverges rather abruptly, but after again describing a part of a circle assumes a direction parallel to that of the free part of the mother theca. The explanation of the first bending is, besides the above given reason, found in the desire of the young zooid to regain, after having budded in a diverging direction, the mother theca as support in further growth; to the second bending it is clearly forced because it has to give to the mother zooid free playroom for its apertural parts. This last curvature causes the deep excavation in the theca. That this is formed to get out of the way of the aperture of the mother, is clearly seen in the fact that the first two thecae [*see* fig. 42] do not possess it, because they, by bending away directly after budding from the sicula, are in their further growth not any more encroaching upon the field of operation of other zooids.

Fig. 46 Dicellograptus gurleyi Lapworth. Fragment preserved in relief. x 7

Where the zooid becomes not only introverted, but also introtorted with its distal part, the next theca is forced to pass around in a correspondingly deeper curve and a deeper excavation results.

The dorsal margin of specimens retaining the periderm is nearly straight or shows but very slight undulations [*see* text fig. 46] and therefore gives little indication of these rather remarkable bends of the somatic cavities. The periderm has, hence, been of considerable thickness on the dorsal side of the branch and by this thickening there assumed the function of a supporting axis.

NOTES ON PHYLOGENY

As the headline implies, it is not intended to give in this place a full account of the phylogenetic relations of the forms here described, but only to bring together a number of notes which have suggested themselves during the prosecution of this work and which bear on the probable phylogeny of these forms.

a On the Phylogeny of the Leptograptidae and Dicranograptidae

The genera Leptograptus and Didymograptus are so similar in their general appearance that the former was not recognized as a separate genus until Lapworth with characteristic keenness discerned the differences in the morphologic characters of their thecae, Didymograptus having the primitive straight tubular theca while that of Leptograptus has a gentle sigmoid curvature and a slightly introverted aperture opening in a shallow excavation of the next theca. Later the same author has united all genera grouping themselves around Leptograptus by this form of the thecae in the family Leptograptidae.

Elles and Wood have pointed out that there is a tendency to the development of this character already observable in some species of Didymograptus, as D. acutidens. The same authors show that also another difference, consisting in the presence of two crossing canals in the Leptograpti against one in the Didymograpti loses its character as absolute differential character by the presence of two crossing canals in D. gibberulus. By the existence of such connecting links the derivation of the Leptograptidae from Didymograptus is distinctly demonstrated.

The compound forms of the Leptograptidae have here been arranged in the genera: Sigmagraptus, Nemagraptus, Syndyograptus, Amphigraptus and Pleurograptus. We have pointed out in Memoir 7 the phylogenetic relations obviously existing between Sigmagraptus and Nemagraptus. The genera Syndyograptus and Amphigraptus possess a peculiar character in common in the paired disposition of the secondary branches, a feature which distinguishes them from all other multiramous forms. Of the two, Syndyograptus is the more primitive in appearance, by the more regular

arrangement of the pairs of branches, which in Amphigraptus are so closely crowded around the center as to produce the appearance of a radiate arrangement. Besides, they may all become compound as in A. multifasciatus and the whole rhabdosome gain in strength and rigidity. Since in Syndyograptus the secondary branches are little diverging, the rhabdosome settles on its side, while in Amphigraptus it rests on its dorsal or ventral side with the branches spreading out on both sides of the main stipes.

The path of the formation of this group is possibly shown by the peculiar centribrachiate form of Leptograptus flaccidus described and figured by Elles and Wood [1903, pl. 14, 15]. In this an extra stipe or branch is present in the center of the rhabdosome which is described as originating from the sicula or its immediate neighborhood and as being either simple or compound. As to its origin it is stated [*op. cit.* p.108]:

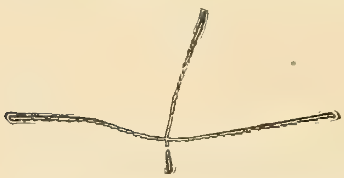


Fig. 47 Leptograptus flaccidus var. macer Elles & Wood. Doubly centribrachiate form. Nat. size

> In these centribrachiate mutations we have been unable to determine with certainty how this third stipe arises. Sometimes it looks as if it were merely the prolongation of the apical part of the sicula, but in other specimens the apex of the sicula is clearly visible. It seems possible that it is an abnormal growth from the initial bud from which the two normal stipes of the polypary are developed, or in other words, it is an extra division of the crossing canal. Thus the branching, instead of being deferred to a late stage in the growth of the polypary, as in the pleurograpti, is concentrated in its early stages.

One specimen of Leptograptus flaccidus var. macer (here copied in text fig. 47) is a doubly centribrachiate individual. In it two branches spring from the center, in another they appear a little away from the center so that one is in doubt whether one should consider it as a centribrachiate form of Leptograptus flaccidus or an Amphigraptus. All these phenomena go to indicate a tendency to extra-division near the center of species of Leptograptus which in some cases produces paired secondary branches and thus would seem to be competent to explain the peculiar phenomenon of paired branches in the genera Syndyograptus and Amphigraptus by similar extra divisions of the connecting canals between the successive thecae of the main stipes.

The monotypic genus Pleurograptus is characterized by its compound secondary branches which are disposed irregularly on the main stipes. Its late appearance in the Champlainic rocks and the character of its main stipes which gradually become wider in distal direction indicate that it also is more probably a derivative of Leptograptus than of Nemagraptus or the earlier Sigmagraptus.

In surveying the various species of Dicellograptus and Dicranograptus, one cannot help noticing the similarities between certain species of the two genera, which suggest a condition similar to that observed in the genera Dichograptus, Tetragraptus and Didymograptus, through which various phyletic lines have been found to pass indicating the polyphyletic nature of these large groups.

Fig. 48 Dicellograptus smithi nov. Sicular portions of rhabdosomes. x 5

In one of our cases a species appears to be directly transitional between two species, one a Dicellograptus, the other a Dicranograptus and thereby clearly to point out the path of development of the latter genus. On account of its importance for the phylogeny of the groups involved, we will state this interesting case more fully.

There is here described a species as Dicellograptus smithi [*see ibid.* and fig. 48], which is remarkable for the variability of its form. On one end it hinges to D sextans with which it has also the dimensions and form of thecae in common, on the other to Dicran. furcatus. Some specimens indeed would be hardly distinguishable from the latter species, were it not for the fact that the spines extend to but a

few of the proximal thecae and for some other minor differences. But the vast majority of the specimens differ distinctly from D. sextans by having the basal parts of the branches subparallel and closely approaching each other. Yet a faint tendency to this approach is already noticeable in D. sextans. Further, D. smithi is distinguished from D. sextans in not having the thecae on the inside of the branches, but alternating on the inside and outside [*see* fig. 48]. This fact and that of the convergence of the branches indicate that the branches grew in a very slender spiral, that leads to the more contracted spiral of forms like Dicranograptus furcatus. Again a slight tendency to a torsion of the branches has been observed in a variety of D. sextans, here described as D. sextans var. tortus. We can, therefore, infer that slight variations already noticeable in the typical sextans and its varieties of the New York Normanskill shale took in the Alabama form a sudden spurt and led to a new species belonging to the more advanced genus Dicranograptus.

To show the close relationship of the three species, we compare their principal characters which pertain to their general appearance in the following table.

	FORM OF RHABDOSOME	DIVERGENCE OF BRANCHES (AXILLARY ANGLE)	WIDTH OF BRANCHES	NUMBER OF THECAE IN 10 MM	CHARACTER OF THECAE
Dicellograptus sextans	Very slender spiral. Slight proximal concavity	60°	.8	11–13	Short, convex ventral walls, apertural part introtorted
Dicellograptus smithi	Slender spiral branches, proximally parallel	60°	.6[1]	12–14	Short, convex ventral walls, apertural part introtorted
Dicranograptus furcatus	Branches forming short spiral, bases coalescent	40–90°	.9–1.1	12–14	Short, convex ventral walls, apertural part introtorted

[1] Less flattened out. Preserved in limestone.

The approach of certain Dicellograpti to Dicranograptus manifests itself in still another feature, that is quite apparent in Dicellogr. sextans, anceps and moffatensis (cf. D. moffatensis var. alabamensis described here), namely in the obliquely outward and upward growth of the four first thecae, whereby a structure exactly corresponding to that in the proximal part of Dicranograptus is produced. D. sextans has probably for this reason been at one time referred to Dicranograptus [Hopkinson 1870], but as Elles and Wood [1904, p. 154] have pointed out in the description of that species: "This form of the proximal end, is practically identical with that of some other species of Dicellograptus, as for example, D. anceps, and varies so little from the more ordinary type exemplified in D. divaricatus, etc., that there is no reason to exclude D. sextans from the genus Dicellograptus on this account," adding, "it may, however, be regarded as one of the intermediate forms connecting this genus with that of Dicranograptus."

Dicellograptus smithi also possesses this "diplograptid" structure of the sicular end in a marked degree. Its combination there with the subparallel direction of the proximal parts of the branches gains a special significance in regard to the phylogeny of Dicranograptus, if it is remembered that also in the biserial portion of most species of Dicranograptus but the four first thecae have an alternate arrangement, while the following are growing in two uniserial series and are separated by a septum. The adnascence of the dorsal walls of D. smithi, already so much approached is, hence, all that is needed to produce a perfect Dicranograptus structure. It is certainly also quite significant that just those species mentioned above as possessing the "diplograptid" structure of the four proximal thecae are also exactly the forms that most distinctly exhibit the tendency to a parallelism or concave curvature, i. e. to a mutual approaching of the proximal parts of the branches. It is, therefore, proper to infer that these species, D. sextans, D. smithi, D. anceps and D. moffatensis are all stages in the evolution of Dicranograpti. But since D. anceps belongs to an entirely different group from the others — having

straight ventral walls of the thecae and straight apertures, while the others have strongly convex ventral walls and introverted and introtorted apertural parts — and D. sextans and smithi are again representative of a phylum different from that of D. moffatensis, — it is quite apparent that this evolution has taken place in several phyla at the same time.

The tendency to a concave curvature of the proximal branches manifests itself still in many other species of Dicellograptus, though more faintly and without combination with the "diplograptid" arrangement of the primary thecae. As examples could be mentioned D. intortus, divaricatus, patulosus, morrisi, forchammeri and elegans.

It is interesting to note just the opposite tendency in Dicranograptus. After the formation of the biserial portion by the adnascence of the subparallel proximal parts of the branches, a tendency to a convexity is developed in the bases of the remaining free uniserial branches. This tendency can be faintly seen even in forms with very straight branches, as D. rectus [*see* Elles & Wood's excellent drawings, pl. 24, fig. 4], D. celticus [*ibid.* fig. 5], D. ramosus [*ibid.* fig. 6 and pl. 23, fig. 2 of this paper] and D. nicholsoni [*ibid.* pl. 25, fig. 1], but it becomes most strongly developed in those forms, where the biserial portion attains its greatest length, viz, D. ramosus, D. spinifer and D. spinifer var. geniculatus. There it leads in its extreme development to a geniculation.

Both these tendencies, that to a parallelism or concavity in the proximal parts of the branches of Dicellograptus[1] and that to a convexity in some parts of the branches in Dicranograptus, are in my opinion, but expressions of a more general tendency of the entire group to a spiral growth of the branches.

That the branches grew in compact spirals in a few species, namely, Dicranograptus furcatus and D. ziczac, can be readily seen

[1] There is also a form of Dicranograptus with subparallel proximal branches, viz, D. cyathiformis Elles & Wood. In this the gradual adnascence is still in progress or just beginning, as the short biserial portion evinces.

from the facts that the branches cross and recross so that they are alternately superjacent at the intersections and that the thecae appear alternately on the outside and inside of the branches [*see* D. furcatus, text fig. 49]. It is here shown that also the branches of Dicellogr. gurleyi [*see* species description] grew in a wide and loose spiral and the same may be claimed for D. caduceus Lapworth. It is further demonstrated in this paper that in D. smithi a tendency to an apparent light torsion or a long spiral growth of the branches already apparent in D. sextans var. tortus is further developed and quite distinctly intermediate between the extremely long spiral of the first named variety and the more contracted spiral of D. furcatus. But in looking over my material and the drawings of foreign species, I can venture the general statement that wherever longer branches of the rhabdosomes are preserved they exhibit the following two features: (1) a final convergence [for example Dicr. ramosus, pl. 21, fig. 6, or D. nicholsoni, in Elles & Wood pl. 25, fig. 1a], however straight and divergent they may have been at first, and (2) a gradual wandering of the thecae from one side of the branch to the other [*see* Elles & Wood; Dicell. morrisi, pl. 21, fig. 6b, c, d; D. moffatensis, *ibid.* pl. 23, fig. 1a; Dicr. brevicaulis, *ibid.* pl. 24, fig. 3a; D. ramosus, *ibid.* pl. 24, fig. 8a; D. nicholsoni, *ibid.* pl. 25, fig. 1a and pl. 20, fig. 3, 5 of this memoir]. These two features, however, point both to the same inference, viz, that of an arrangement of the branches in two long spirals, passing equidistally on the surface of an imaginary double cone.

The advantages of such an arrangement are quite apparent; they consist first in the possibility of increasing the length of the branches without pushing the distal part of the rhabdosome too far away from the center of the colony and second in imparting the elasticity of a spiral to the rhabdosome, thereby protecting it against being broken or torn off.

It can further be easily seen how the two spirals of the branches would when disturbances occurred have exerted a special strain at the distant point where they were united, i. e. at the sicular end; hence the tendency to

strengthen this point by the "diplograptid" mode of growth, the coalescence of the proximal parts of the branches and the "web," for it can not be doubted that the upward growth of the primary thecae in the more advanced Dicellograpti and in all Dicranograpti and the coalescence of the branches tend all to the same end, namely that of producing a long and firm connection at the most exposed extremity of the two branches. This tendency has, in my opinion, been the cause of the development of the peculiar Dicranograptus structure, with its biserial proximal portion, from Dicellograptus.

Frech has sought the explanation of the structure of Dicranograptus in the assumption that the biserial portion served like the "fins" of the Diplograpti and Monograpti to permit a steering in vertical direction and suggested that the two branches were united by a membrane which was not preservable in fossil state. While this view has the advantage of being part of a general proposition, viz, that the expansions of the sicular ends of all Axonolipa served as rudders, it seems in this special case not so well supported or even contradicted by the observations stated before, for the inference of the growth of the branches in elastic spirals is difficult of reconciliation with that of a terminal rudder which requires a rigid rudder pole. Nor is there any tendency to a broadening of the biserial section noticeable in any Dicranograpti, while the origin of the biserial portion finds a plausible explanation as a corollary of the spiral growth of the branches.[1]

The further assumption of the presence of an extensive membrane stretched between the branches for purposes of steering, would also be invalidated by the inference of the spiral growth of the branches.

The nature of the antisicular or inner end of the branches is still a mystery. Frech, who first noticed that the branches of large specimens of Dicranograptidae which at first diverge, converge again later on, has based a reconstruction of Dicranograptus and Dicellograptus on this observation, and introduced a semidiagrammatic figure [1897, p.619] in which the

[1] If one, with Frech derives Dicellograptus through Dicranograptus from Climacograptus, the biserial portion is anyway but a disappearing and transitional structure.

branches finally reapproach without, however, uniting and thus terminate at the central organs. This is the only hypothesis on the structure of the perfect colony of a Dicranograptid known to me.

Diligent search on my part for specimens giving clues on the structure of these antisicular ends has met with very little success and the solution of the problem is evidently only to be expected from the fortunate discovery of perfect synrhabdosomes. With few exceptions all specimens are distinctly broken at the antisicular extremities. None have shown any protruding nemas by which they could have fastened themselves to the central organs with the exception of a young rhabdosome of a Dicranograptus in which the biserial portion is not yet completed [*see* text fig. 41]. This interesting specimen indicates that the growth of the biserial portion of the rhabdosome took place as in Diplograptus and Climacograptus along the nema connecting the sicula with the primary disk. What, however, held the rhabdosome after the completion of its first portion we do not know. So much seems certain that the nema did not continue into any of the branches as axis.[1] A few specimens of seemingly perfect rhabdosomes of Dicranograptidae were seen to fade out at the antisicular extremities of the branches as if there had been the growing ends and the periderm of the thecae not yet fully secreted.

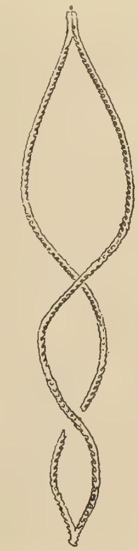


Fig. 49 Dicranograptus furcatus (Hall). Rhabdosome showing two successive crossings. The upper branch is partly broken away at the first crossing. Normanskill shale, Stockport, N. Y. Original in National Museum. Nat. size

A specimen of Dicranograptus furcatus [*see* fig. 49] deserves particular notice in this connection. This shows two successive crossings of the originally spiral branches, but where the third crossing would be expected the two branches lie in juxtaposition for about 5 mm, the slab being unfortunately broken off at that point. One end shows the ventral, the other the dorsal side, and the former overlaps the latter a little, thus giving the impression that the two branches were in contact with their dorsal sides without coalescing and pushed a little side-

[1] See discussion of the presence of a "virgula" in the Dicranograptidae on page 102.

ways in becoming buried in the mud. Since this is the most perfect specimen of this species observed, it is quite possible that we have here before us a part of the original antisicular end of the rhabdosome and that at that end the branches were in contact.

If, of the two genera Dicellograptus and Dicranograptus, we have good reason to consider the former as the more primitive one and as having led to the development of the latter, we are further induced to infer that this development took place along various racial lines, this inference basing itself on a number of similarities between species of the two genera which find their expression partly in the like form of the thecae and partly in the like habit of the rhabdosomes. Elles and Wood have divided both genera in four subdivisions [here recognized] by the character of the ventral walls of the apertures of the thecae. These groups run completely parallel in both genera, i. e. we find in both all stages between forms whose thecae have straight ventral walls and horizontal apertures and forms in which the thecae have markedly curved ventral walls and strongly introverted and introtorted apertural portions. The inference suggests itself from these facts that a number of forms with primitive, little sigmoidally curved thecae developed directly into Dicranograpti by the coalesence of the sicular portion of the rhabdosome without further advancing the form of the thecae. There exist likewise such similarities in the habits of the forms of the corresponding divisions of the two genera, that their direct phylogenetic connection can not be doubted.

The genus Dicellograptus again is connected by many obvious bands of relationship with Leptograptus, thereby indicating the derivation of the Dicranograptidae from the Leptograptidae. This relationship shows itself most distinctly in the thecae which in the development of the sigmoid curvature and the depth of the excavation graduate by a continuous line of transitions from the Leptograpti with their shallow excavations and gently curved thecae to the Dicellograpti of the first subdivision. In some forms one is consequently in doubt as regards the character of the thecae, to which of the two genera one is to refer it. Elles and Wood have also shown that

the sicula of Dicellograptus is of the same type as that of Leptograptus and that the development of the proximal or sicular end of the rhabdosome is essentially similar to that in Leptograptus as regards (1) the presence of two crossing canals, and (2) the alternate development of the four primary thecae.

The spines which originally were apertural, because the aperture was the most prominent part of the theca, wander backward in the Dicellograpti owing to the bulging out of the mesial part of the theca through the sigmoid curving of the latter, and again fix themselves on the most prominent part of the theca, i. e. the mesial boss. The differentiation in the position of the spines is for this reason also to be considered as lying in the line of the general development of the Dicranograptidae.

The whole rhabdosome of Leptograptus is typically more flexuous as expressed in the name of its typical species L. flaccidus, and that of Dicellograptus more rigid and in the whole, also much thicker. Owing to the horizontal growth of the four primary thecae in Leptograptus and the upward growth of the third and fourth theca in Dicellograptus, the former has a wide open axil and the latter a narrower one, a differential character which obviously leads from Leptograptus to Dicranograptus.

If we remember that the Leptograptidae were probably derived from a subdivision of Didymograptus and contrast the mode of fixation by nema and primary disk in the latter with that which probably obtains among the Dicranograptidae, viz, by the distal ends of the branches, it can be well understood how the discarding of the original mode of fixation has brought about all these changes. It leads to the origination of a strain in the branches which has been overcome by their thickening, and to a still greater strain in the sicular end of the rhabdosome which as we have noted before [*see* p.113] has led to the approach of the dorsal sides of the proximal parts of the branches — or a diminution of the axil — and to the final coalescence of these sides in Dicranograptus, as well as to the adoption of a special growth of the branches.

The combination of the strong endeavor to hide and protect the aper-

tures by introversion and introtortion with the apparent anxiety to remove the rhabdosome from the base of fixation give one the impression that some, probably creeping enemy had appeared on the seaweeds which threatened the zooids. It may have been such influences that led to the adoption of a holoplanktonic mode of life by the Axonophora.

b On the phylogenetic relations of the genera of the Graptoloidea Axonophora

The abrupt appearance of some of the principal genera of the Graptoloidea Axonophora in the third Deepkill zone and the slight indications of phylogenetic relationship between the Axonolipa and Axonophora that have thus far been discovered, have been discussed in Memoir 7 [p.550 ff]. It has been set forth there that the principal new acquisitions of the Axonophora are the further complication of the colonies into synrhabdosomes and the development of a solid axis (virgula) as support of the nemacaulus after the latter has become incorporated in the rhabdosome as the "axis," giving to the order its name.

The astogeny of the Axonophora as described by the writer in 1895 [*see also* Mem. 7, p.528] appears to demonstrate by such stages as that reproduced p.528, fig. 4, where a single (primary) rhabdosome is suspended from the primary disk, the derivation from forms with simple rhabdosomes such as the Dichograptidae have. This stage could be readily conceived to be produced by the further continuation of the alternate mode of development of the thecae begun in Didymograptus caduceus [*see ibid.* p.550 ff]. From the primary disk or the base of the nemacaulus vesicular bodies filled with siculae grow forth. These have been described by the writer as gonangia and considered as organs of sexual reproduction while Wiman has urged their character as budding individuals. However that may be, it is obviously the production and remaining attached of these siculae which leads to the formation of the new rhabdosomes that combine in the synrhabdosome. It is quite certain that the production of the siculae at the base of the nemacaulus is a feature inherited from the Axonolipa. While the siculae of the latter are well known, the place of their origin has not yet been observed, and since all facts point to a derivation of the

Axonophora from the Axonolipa the proper inference is that in the latter the siculae were produced in the same locality, i. e. at the base of the nemacaulus or on the primary disk; but with the difference that in the Axonolipa they all were discharged and in the Axonophora only a part, the remainder growing out to additional rhabdosomes.

Another astogenetic character, at least of the genera Diplograptus and Climacograptus, that bears on the phylogeny of the Axonophora is the initial downward growth of the first theca of the rhabdosome along the sicula [*see* text fig. 6]; for this can not be otherwise explained than as a relic of the time when all thecae of the rhabdosome grew forward or away from the center of the rhabdosome, as they did in the majority of the Axonolipa.

The origin and position of the virgula within the nemacaulus has been briefly noted by the writer in Memoir 7 [p.551] and the evidence of its general existence in the Axonophora more fully given in this paper [*antea* p.96]. As the first step to its formation we may probably consider the thickening of the dorsal wall of the common canal in certain Dichograptidae, as Tetragraptus amii [*see* Mem. 7, p.552], for it is probable from this that the solid rod has become separated in the course of further development. Its first appearance in the sicula in the astogeny of the Axonophora we have there considered as a case of tachygenetic transference of a character acquired in later development to the embryonic or postembryonic stage (the sicula).

The statement made in Memoir 7 with special reference to the Dicranograptidae, that the virgula of the Axonophora may not be an homologous organ in all genera, has lost its meaning by the recognition that the Dicranograptidae do not have any virgula and are properly considered as Graptoloidea Axonolipa [*see* p.102].

Both *Diplograptus* and *Climacograptus* appear side by side in the third Deepkill zone before any of the Dicranograptidae have come on the scene, and their chronological order hence invalidates possible attempts to connect the Climacograptidae — and eventually also the Diplograptidae — with the

Dicranograptidae on account of their sigmoid thecal form and the alternate mode of growth of the thecae in the lower biserial portion of Dicranograptus. The primitive straight form of the thecae of Diplograptus points to Didymograptus and the sigmoid curvature of those of Climacograptus to Leptograptus as the probable progenitors. Although the Leptograptidae do not attain their acmic development until Trenton and later ages, they appear early enough (Middle and Upper Skiddaw slates) to possibly have furnished, in their earliest forms, the starting points of the phyla of the Climacograptidae.

Whether Diplograptus and Climacograptus also represent polyphyletic groups such as Dichograptus, Tetragraptus and Didymograptus have been found to be, instead of true genera [*see* Mem. 7, p.553 ff], can not be ascertained until the phyla which apparently exist within them [*see* descriptions] have been traced backward into their ancestral "genera." The fact, however, that there exist not only such phyla within the two genera but also very considerable differences in the form of the thecae would seem to strongly suggest their polyphyletic character. These differences become especially apparent in the genus Climacograptus where all stages from the nearly straight Diplograptuslike thecae to highly sigmoidally curved ones with slightly introverted apertures can be found. Such a form which seems to stand between Diplograptus and Climacograptus is C. putillus which on account of the very gentle curvature of its thecae has been currently cited as Diplograptus putillus.

Diplograptus dentatus of the third Deepkill zone is undoubtedly the first ancestor appearing in our rocks of the subsequently so powerful stock of D. foliaceus and its varieties and mutations, on one hand, and D. angustifolius and D. euglyphus on the other.

Climacograptus pungens, the first Climacograptid appearing in the third Deepkill zone is distinctly a member of the same race with C. putillus, C. typicalis, mississippiensis, and ulrichi. The close relationship of these forms is shown in their thecae, which are furnished with mesial mucros and slightly everted apertures, and in the

character of the sicular end of the rhabdosome. C. innotatus Nicholson of the British Birkhill shales is clearly a Siluric derivative of the same phylum. The details of the relationships of these forms are more fully given in the species descriptions. It will suffice, therefore, to state here that C. putillus and its earlier mutation eximius have most fully preserved the characters of C. pungens, although the mesial spines have become markedly reduced, a fact which but ill accords with the general tendency to increased spinosity in the later forms of a race; and further that C. typicalis is in its sicular portion still a typical C. putillus, but as the astogenetic development of its rhabdosome suggests, it has under favorable conditions grown to dimensions which much contrast with those of putillus. While the direct putillus race apparently persisted in the Levis basin, C. typicalis comes in with the Utica transgression and has hence been developed in another region. It persisted however in the American epicontinental sea in forms which exhibit a distinct tachygeny in their astogenetic development. The European species C. minimus and brevis are vicarious forms of C. putillus which are most closely related to it; likewise C. latus corresponds to our C. typicalis rather than to the later derivatives of the same described here from the West.

There is also little doubt especially from the character of its sicular extremity and the neastic thecae that C. scalaris, a form of world-wide distribution in the Siluric is to be derived from the stock of C. putillus. It appears already in the closing stages of the Champlainic (Lower Siluric) in a variety (C. scalaris var. miserabilis Elles & Wood) that both in its dimensions and thecal characters is but little different from C. putillus and quite readily can be derived from it.

The other Climacograptidae, here described, practically all appear together without any preceding forms to which they could be referred. They naturally fall in several groups which are more or less related to each other apparently without forming distinct phylogenetic lines. C. antiquus, C. caudatus and C. parvus are closer related to each

other than the remaining species; C. antiquus being the probable ancestor of C. caudatus; C. modestus forms together with C. scharenbergi a natural group; and C. bicornis represents another group.

We have before set forth that, in our opinion, the development of apertural spines has induced the formation of a system of supporting ledges, lateral axes, and fibers within the periderm and has thus, combined with the influence of the obvious tendency of the holoplanktonic graptolites to lighten their periderm without accruing loss of strength [*see* Mem. 7, p.518], led finally to structures as we find them in the genera Retiograptus and Retiolites. It is here shown under the heading *Glossograptus* that forms which have hitherto been considered as typical Diplograpti, as notably D. quadrimucronatus, may already under the thick outer periderm possess the structure above referred to. We have, for this reason, referred these forms to Glossograptus. But it is evident that such a form which in all its external features is still a typical Diplograptus, is transitional from Diplograptus to Glossograptus. Since highly spinose types of Glossograptus appear already in the third Deepkill zone, together with the other early Axonophora, it is probable that the Glossograpti developed from different stocks at different times and that the genus is polyphyletic. How rapid the development has been at the dawn of the order Axonophora is clearly evinced by the fact that also Retiograptus appears already side by side with Diplograptus and Glossograptus.

Retiograptus eucharis has been here, on account of its spinosity, referred with some doubt to Glossograptus. It certainly is not congeneric with the genotype of Retiograptus (R. tentaculatus) and has the thecae of a Diplograptus. We are probably not far from the truth in considering it, on account of its thecal form, as a descendant of Diplograptus inutilis, a species of the third Deepkill zone, for both possess not only similar small dimensions but also the same concave outer margins of the thecae and slightly recurving denticles; and D. inutilis already exhibits a distinct tendency to the formation of spines at the thecal aper-

tures. The connecting species of Trenton age has, however, not yet been observed, the development of the Utica species Glossograptus eucharis having obviously taken place in the Atlantic basin. Glossograptus ciliatus, the genotype and representative of the genus in the Normanskill shale does not — as noted before — suggest by its form any relationship to G. quadrimucronatus, but appears rather as a direct descendant of G. echinatus, a Deepkill form, which it resembles in all important features.

A form which in its external appearance by its subrectangular section, smooth broad lateral sides and the form of the aperture [*see* pl. 31, fig. 17], as well as in its peridermal skeleton [*ibid.* fig. 16] also recalls G. quadrimucronatus is Clathrograptus geinitzianus Hall, one of our most interesting Normanskill forms, but also one of the most difficult of reconstruction. It possesses a strong outer periderm, a system of ledges corresponding to that of G. quadrimucronatus but apparently lacks the network of fibers, the apertural spines and the virgula, and since it also appears before G. quadrimucronatus quite probably represents an independent but subparallel development wholly induced by the tendency to a lightening of the periderm. While in Glossograptus the virgula is still well preserved besides the two lateral axes [*see* pl. 26, fig. 9], in Clathrograptus geinitzianus only two zigzag shaped lateral axes have been observed.

The Siluric genus *Retiolites* represented here by our Clinton species R. venosus possesses a like framework of ledges as Clathrograptus with the distinction that one of the lateral ones is zigzag shaped and the other straight [pl. 31, fig. 8]. It lacks all spines and the reduction of the continuous periderm to a fibrous network covered by a very thin cuticle is distinctly intended to reduce the weight of the periderm. Both genera, Retiolites which has the thecae of a Diplograptus, and Gothograptus which has those of a Climacograptus have apparently independently developed from the genera mentioned here with them, and after them, viz, in Siluric time.

In several respects one of the most peculiar genera here under investigation is *Lasiograptus.* Its species usually appear as rather lax rhabdosomes with apertural spines or fibers [pl. 29, fig. 9–14], which often reached considerable length and sometimes are observed to connect with each other. At times also larger subtriangular appendages have been observed which suggest cystlike organs and have been considered as gonangia. We have, on the strength of some very favorably preserved specimens, attempted here a reconstruction [pl. 31, fig. 5] according to which the fibers, triangular appendages and shreds of fine network are parts of outer continuations of the thecae. In this group either the reduction of the periderm of the thecae has affected but the distal halves of the thecae on the lateral sides, or an original spinosity has led to the development of an outer protecting structure permitting a safe longitudinal growth of the zooids.

Fig. 50 Climacograptus retioloides Wiman. x 32 (Copy from Wiman)

In the discussion of the genus Lasiograptus in this memoir the details of the structure of Lasiograptus are more fully described and several reasons advanced for the view that the reticulate outer structures are new acquisitions of the genus. The principal of these reasons are the astogenetic development of the rhabdosome [*see* pl. 29, fig 16] which indicates a later appearance of the outer reticulate structure than the inner halves, and the relations obviously existing between Climacograptus retioloides and Lasiograptus. The former species, as set forth more fully under Lasiograptus, possesses horizontal bandlike thickenings of the middle layer of the periderm [*see* text fig. 50] which are connected with recurving loops proceeding outward from the ventral walls. Like horizontal ledges are seen in macerated specimens of Lasiograptus [pl. 29, fig 15; pl. 30, fig. 2, 7] and the loops of C. retioloides quite obviously correspond to the fibrous loops on which the distal structures of Lasi-

ograptus rest. Since also the thecae of C. retioloides and Lasiograptus are remarkably similar there is little doubt that the former points out the path of development of Lasiograptus. If, however, this view of the origin of Lasiograptus is correct, it is evident that the reticulate outer structures of the thecae of that genus are of secondary origin. The peculiar contraction of the triangular appendages towards their base is also quite significant in this connection since it shows that these appendages which separate the distal parts of the zooids are not merely prolongations of the thecal walls but new formations, starting from the bases of the loops of Climacograptus retioloides.

We have in the foregoing discussion of Lasiograptus contrasted the outer reticulate structure of the thecae with the solid periderm of the latter. There is, however, good reason to assume that this continuous periderm partakes also of the nature of the reticulate walls of the Retiolitidae but is covered with a thin continuous layer similarly as in Retiolites. The main reason for this view is that the rhabdosome of Lasiograptus never possesses the strong gloss of the solid walled forms as Dicranograptus and Diplograptus but is always of a dull black color and gives the impression of original tenuity. Furthermore we have observed in somewhat macerated specimens indications of the presence of a system of stronger marginal ledges recalling the structures found in other Retiolitidae [*see* pl. 31, fig. 8]. The latter observation is also to be considered as a further argument for the completeness of the proximal parts of the thecae and the secondary origin of the outer structure.

A like dullness of the periderm indicating great tenuity of the walls is a characteristic feature of the species of *Cryptograptus* which as well as the punctate nature of the test have already been pointed out in Lapworth's diagnosis of the genus. We have material in hand, which demonstrates the presence of stout apertural rings of the sicula and a system of marginal ledges of the thecae [*see postea*]. The combination of the punctate and much attenuated test with the presence of these ledges leaves hardly any doubt that this well defined group of forms has already reached the retio-

loid stage of development when it is first observed in the third Deepkill zone.

We believe that the just mentioned characters of the periderm also serve to indicate a closer relationship between Cryptograptus and Lasiograptus. It is in this connection important to note that also the general aspect of the rhabdosomes of the two genera, as well as that of the thecae show many points of agreement, as the great difference in width between the frontal and lateral aspects, the lax appearance of the rhabdosome in the lateral aspect and the arcuate form of the thecae with a short perpendicular distal outer wall. Cryptograptus appears long before Lasiograptus in the third Deepkill zone with C. antennarius and continues into and through the hemera of Lasiograptus with a species (C. tricornis) but little different from and clearly a descendant of the former.

The Deepkill form still possesses such strong climacograptoid features that in Memoir 7 we have referred it — with doubt — to that genus and consider it entirely probable that it took its origin from an early climacograptid stock. There is good reason to infer that Lasiograptus was derived independently from Cryptograptus from the same stock. As both Lasiograptus and Cryptograptus also still retain distinct diplograptid features, it is entirely proper to further infer their derivation from primitive Climacograpti still little differentiated from Diplograptus.

Since the reticulation of the periderm itself has not yet been observed in Cryptograptus, we have here not placed this genus with the Retiolitidae where it eventually may find its place, but have indicated its transitional character to the latter family by its terminal position in the Diplograptidae.

SYNOPTIC LIST OF GRAPTOLITES NOTED IN THIS VOLUME

Species in parenthesis are rejected

Order I DENDROIDEA Nicholson

Family DENDROGRAPTIDAE Roemer

Genus DENDROGRAPTUS Hall

Dendrograptus rectus *sp. nov.*

Genus CALLOGRAPTUS Hall

Callograptus compactus (*Walcott*)

Genus PTILOGRAPTUS Hall

Ptilograptus poctai *sp. nov.*

P. hartnageli *sp. nov.*

Genus DICTYONEMA Hall

Dictyonema neenah *Hall*

D. obovatum *Gurley*

D. spiniferum *sp. nov.*

D. arbuscula (*Ulrich*)

D. pertenue *Foerste*

D. scalariforme *Foerste*

D. retiforme *Hall*

D. gracile *Hall*

D. polymorphum *Gurley* ms

D. subretiforme (*Spencer*)

D. areyi *Gurley* ms

D. crassum *Girty*

D. leroyense *Gurley* ms

D. megadictyon *Gurley* ms

D. perradiatum *Gurley* ms

D. fenestratum *Hall*

D. hamiltoniae *Hall*

D. blairi *Gurley*

Genus ODONTOCAULIS Lapworth

Odontocaulis hepaticus *sp. nov.*

Genus PTIOGRAPTUS nov.

Ptiograptus percorrugatus *sp. nov.*

Genus DESMOGRAPTUS Hopkinson

Desmograptus tenuiramosus *sp. nov.*

Desmograptus pergracilis (*Hall & Whitfield*)

D. becraftensis *sp. nov.*

D. cadens (*Hall*)

D. vandelooi *sp. nov.*

Genus CYCLOGRAPTUS Spencer

Cyclograptus rotadentatus *Spencer*

Genus INOCAULIS Hall

Inocaulis plumulosus *Hall*

I. divaricatus *Hall*

I. flabellum (*Miller & Dyer*) *James*

Genus ACANTHOGRAPTUS Spencer

Acanthograptus walkeri *Spencer*

Genus CACTOGRAPTUS *nov.*

Cactograptus crassus *sp. nov.*

Genus PALAEODICTYOTA Whitfield emend. Ruedemann

Palaeodictyota anastomotica (*Ringueberg*)

P. clintonensis *sp. nov.*

P. bella (*Hall*)

mut. recta *nov.*

Genus THAMNOGRAPTUS Hall

Thamnograptus capillaris (*Emmons*)

Genus MASTIGOGRAPTUS nov.

Mastigograptus tenuiramosus (*Walcott*)

M. simplex (*Walcott*)

M. gracillimus (*Lesquereux*)

M. arundinaceus (*Hall*)

M. circinalis *sp. nov.*

INCERTAE SEDIS

Genus CHAUNOGRAPTUS Hall

Chaunograptus novellus *Hall*

C. gemmatus *sp. nov.*

C.? rectilinea *sp. nov.*

Genus CORYNOIDES Nicholson

Corynoides calicularis *Nicholson*

C. gracilis *Hopkinson*

mut. perungulatus *nov.*

C. curtus *Lapworth*

var. comma *nov.*

Genus PROTOVIRGULARIA McCoy

cf. Protovirgularia dichotoma *McCoy*

REJECTED GENERA

Genus PHYCOGRAPTUS Gurley

Genus MEGALOGRAPTUS Miller

Order II GRAPTOLOIDEA Lapworth

Suborder A GRAPTOLOIDEA AXONOLIPA Frech em. Ruedemann

Family DICHOGRAPTIDAE Lapworth

Genus DIDYMOGRAPTUS McCoy

Didymograptus sagitticaulis *Gurley*

D. serratulus (*Hall*)

D. subtenuis (*Hall*)

(Didymograptus ? elegans *Emmons*)

(D. rectus *Emmons*)

Genus AZYGOGRAPTUS Nicholson

Azygograptus walcotti *Lapworth*

A.? simplex *sp. nov.*

Family LEPTOGRAPTIDAE Lapworth

Genus LEPTOGRAPTUS Lapworth

Leptograptus flaccidus (*Hall*) *mut.* trentonensis *nov.*

L. flaccidus (*Hall*) *var.* spinifer *Elles & Wood*

mut. trentonensis *nov.*

mut. trifidus *nov.*

L. annectans (*Walcott*)

Genus SYNDYOGRAPTUS gen. nov.

Syndyograptus pecten *sp. nov.*

Genus PLEUROGRAPTUS Nicholson

Pleurograptus linearis (*Carruthers*)

Genus AMPHIGRAPTUS Lapworth

Amphigraptus divergens (*Hall*)

A. multifasciatus (*Hall*)

Subfamily NEMAGRAPTIDAE Ruedemann

Genus NEMAGRAPTUS Emmons

Nemagraptus gracilis (*Hall*)

var. surcularis (*Hall*)

var. crassicaulis *Gurley*

var. distans *nov.*

var. approximatus *nov.*

Nemagraptus exilis *Lapworth*

var. linearis *nov.*

Family DICRANOGRAPTIDAE Lapworth

Genus DICELLOGRAPTUS Hopkinson

Dicellograptus *cf.* complanatus *Lapworth*

D. mensurans *sp. nov.*

D. divaricatus (*Hall*)

var. salopiensis *Elles & Wood*

var. rigidus *Lapworth*

var. rectus *nov.*

var. bicurvatus *nov.*

D. intortus *Lapworth*

D. gurleyi *Lapworth*

Dicellograptus sextans (*Hall*)
var. exilis *Elles & Wood*
var. perexilis *nov.*
var. tortus *nov.*
D. moffatensis (*Carruthers*) *var.* alabamensis *nov.*
D. elegans (*Carruthers*)
D. smithi *sp. nov.*

Genus DICRANOGRAPTUS Hall

Dicranograptus nicholsoni *Hopkinson*
var. parvangulus *Gurley*
var. diapason *Gurley*
var. whitianus *Miller*
D. ramosus *Hall*
var. arkansasensis *Gurley*
D. spinifer *Elles & Wood*
var. geniculatus *nov.*
D. furcatus (*Hall*)
var. exilis *nov.*
D. contortus *sp. nov.*

Suborder B GRAPTOLOIDEA AXONOPHORA Frech

Family DIPLOGRAPTIDAE Lapworth

Genus DIPLOGRAPTUS McCoy

Diplograptus foliaceus (*Murchison*)
var. incisus *Lapworth*
var. acutus *Lapworth*
var. trifidus *Gurley*
var. alabamensis *nov.*
mut. vespertinus *nov.*
D. crassitestus *sp. nov.*
(D. dissimilaris *Emmons*)
(D. laciniatus *Emmons*)
(D. obliquis *Emmons*)
(D. rugosus *Emmons*)
(D. simplex *Emmons*)
D. (Glyptograptus) amplexicaulis *Hall*
var. pertenuis *nov.*
D. (Glyptograptus) angustifolius *Hall*
D. (Glyptograptus) euglyphus *Lapworth*
var. pygmaeus *nov.*
D. peosta *Hall*

Genus GLOSSOGRAPTUS Emmons

Glossograptus ciliatus *Emmons*
mut. horridus *nov.*
var. debilis *nov.*
G. (Orthograptus) quadrimucronatus (*Hall*)
var. approximatus *nov.*
var. cornutus *nov.*
mut. postremus *nov.*
G. whitfieldi (*Hall*)
G.? eucharis (*Hall*)

Genus CLIMACOGRAPTUS Hall

Climacograptus typicalis *Hall*
mut. spinifer *nov.*
C. ulrichi *sp. nov.*
C. mississippiensis *sp. nov.*
C. putillus (*Hall*)
mut. eximius *nov.*
C. parvus *Hall*
C. modestus *sp. nov.*
C. scharenbergi *Lapworth*
C. scalaris (*Hisinger*) *var.* (*mut.*?) annulatus *nov.*
C. bicornis *Hall*
C. antiquus *Lapworth*
C. cf. oligotheca *Gurley*
C. caudatus *Lapworth*

Genus CRYPTOGRAPTUS Lapworth

Cryptograptus tricornis (*Carruthers*)
mut. insectiformis *nov.*

Family MONOGRAPTIDAE Lapworth

Genus MONOGRAPTUS Geinitz

Monograptus clintonensis (*Hall*)

M. priodon (*Bronn*) *mut.* chapmanensis *nov.*

M. beecheri *Girty*

Genus CYRTOGRAPTUS Carruthers

Cyrtograptus ulrichi *sp. nov.*

Family RETIOLITIDAE Lapworth

Genus RETIOGRAPTUS Hall

Retiograptus geinitzianus *Hall*

Genus RETIOLITES Barrande

Retiolites geinitzianus *Barrande var.* venosus *Hall*

Genus LASIOGRAPTUS Lapworth

Lasiograptus mucronatus (*Hall*)

L. bimucronatus *Nicholson mut.* timidus *nov.*

SYNOPTIC AND SYNONYMIC LIST OF THE GRAPTOLITES RECORDED FROM NORTH AMERICA

The forms occurring in New York State are distinguished by an asterisk. Synonyms are printed in italics. The genera are arranged alphabetically within the three orders, here recognized.

Order 1 DENDROIDEA Nicholson

Acanthograptus *Spencer*, 1878
  granti *Spencer*, 1878
  pulcher *Spencer*, 1884
  *walkeri (*Spencer*), 1884
Cactograptus *Ruedemann*, 1907
  *crassus *Ruedemann*, 1907
Callograptus *Hall*, 1865
  *compactus (*Walcott*), 1879
  *diffusus (*Hall*), 1865
  elegans *Hall*, 1865
  granti *Spencer*, 1884
  minutus *Spencer*, 1884
  multicaulis *Spencer*, 1884
  niagarensis *Spencer*, 1878
  *salteri *Hall*, 1865
Calyptograptus *Spencer*, 1878
  cyathiformis *Spencer*, 1878
C. micronematodes *Spencer*, 1884
  radiatus *Spencer*, 1884
  **subretiformis* Spencer, 1878
    [*see* Dictyonema]
Cyclograptus *Spencer*, 1884
  *rotadentatus *Spencer*, 1884
Dendrograptus *Hall*, 1865
  **arundinaceus* (Hall) Gurley
    [*see* Mastigog.]
  **compactus* Walcott, 1879
    [*see* Callog.]
  dawsoni *Spencer*, 1884
  **diffusus* Hall, 1865
    [*see* Callog.]
  divergens *Hall*, 1865
  dubius *Miller*, 1889
  erectus *Hall*, 1865

*Dictyonema subretiforme (*Spencer*), 1878
tenellum *Spencer*, 1878
websteri *Dawson*, 1860
Inocaulis *Hall*, 1852
**anastomoticus* Ringueberg, 1888
[*see* Palaeodictyota]
arbuscula Ulrich, 1879
[*see* Dictyonema]
bellus Hall & Whitfield, 1875
[*see* Palaeodictyota]
cervicornis *Spencer*, 1884
diffusus *Spencer*, 1884
divaricatus *Hall*, 1879
flabellum (*Miller & Dyer*) *James*
(No graptolite)
phycoides *Spencer*, 1884
*plumulosus *Hall*, 1851
?problematicus *Spencer*, 1878
ramulosus *Spencer*, 1884
**walkeri* Spencer, 1884
[*see* Acanthog.]
Mastigograptus *Ruedemann*, 1907
*arundinaceus (*Hall*), 1847
*circinalis *Ruedemann*, 1907
gracillimus (*Lesquereux*), 1878
*simplex (*Walcott*), 1879
**Nemagraptus capillaris* Emmons, 1855
[*see* Thamnog.]
Odontocaulis *Lapworth*, 1881
*hepatica *Ruedemann*, 1907

Palaeodictyota *Whitfield*, 1902
*anastomotica (*Ringueberg*), 1888
*clintonensis *Ruedemann*, 1907
bella (*Hall*), 1875
**mut.* recta *Ruedemann*, 1907
Ptilograptus *Hall*, 1865
foliaceus *Spencer*, 1878
*geinitzianus *Hall*, 1865
*hartnageli *Ruedemann*, 1907
*plumosus *Hall*, 1865
*poctai *Ruedemann*, 1907
*tenuiramosus *Ruedemann*, 1904
Ptiograptus *Ruedemann*, 1907
percorrugatus *Ruedemann*, 1907
**Rastrites barrandii* (Hall)
[*see* Thamnog. capillaris]
Rhizograptus *Spencer*, 1878
bulbosus *Spencer*, 1878
Thamnograptus *Hall*, 1859
affinis *Whiteaves*, 1897
anna *Hall*, 1865
barrandii (Hall)
[*see* Th. capillaris]
bartonensis *Spencer*, 1878
*capillaris (*Emmons*), 1855
?multiformis *Spencer*, 1878
**typus* Hall, 1859
[*see* T. capillaris]

Order 2 GRAPTOLOIDEA AXONOLIPA

Amphigraptus *Lapworth*, 1873
*divergens (*Hall*), 1859
*multifasciatus (*Hall*), 1859
Azygograptus *Nicholson*, 1875
*(?)simplex *Ruedemann*, 1907
*walcotti *Lapworth*, 1896

Bryograptus *Lapworth*, 1880
*lapworthi *Ruedemann*, 1904
lentus *Matthew*, 1895
(*cf.* Staurog. dichotomus)
*(?)*multiramosus* Gurley, 1896
(=Dictyon. flabelliforme)

*Dicranograptus contortus *Ruedemann*, 1907
dissimilaris (Emmons), 1856
(=Dicranog. sp. indet.)
**divaricatus* (Hall), 1859
[*see* Dicellog.]
*furcatus (*Hall*), 1847
**var.* exilis *Ruedemann*, 1907
?inequalis (*Emmons*), 1856
(=?Dicranog. sp. indet.)
*nicholsoni *Hopkinson*, 1870
var. *arkansasensis* Gurley, 1896
[*see* Dicr. ramosus]
**var.* diapason *Gurley*, 1896
**var.* parvangulus *Gurley*, 1892
var. whitianus *Miller*, 1893
*ramosus *Hall*, 1847
var. arkansasensis (*Gurley*), 1896
rectus *Hopkinson*, 1872
**sextans* (Hall), 1847
[*see* Dicellog.]
*spinifer *Elles & Wood*, 1904
**var.* geniculatus *Ruedemann*, 1907
Didymograptus *McCoy*, 1851
*acutidens *Lapworth*, 1901
arcuatus (*Hall*), 1865
*bifidus (*Hall*), 1858
bipunctatus *Gurley*, 1896
*caduceus (*Salter*), 1853
**mut.* nanus *Ruedemann*, 1904
**constrictus* (Hall), 1858
(=D. extensus *et al.*)
**convexus* Gurley, 1896
(=sagitticaulis Gurl.)
*cuspidatus *Ruedemann*, 1904
(?)elegans (*Emmons*), 1856
*ellesae[1] *Ruedemann*, 1904

D. euodus *Lapworth*, 1875
*extensus (*Hall*), 1858
extenuatus (*Hall*), 1865
*filiformis *Ruedemann*, 1904
*forcipiformis *Ruedemann*, 1904
furcillatus *Lapworth*, 1875
*gracilis *Törnquist*, 1891
hirundo *Salter*, 1863
*incertus *Ruedemann*, 1904
indentus (*Hall*), 1858
var. *nanus* Lapworth, 1875
(=nanus)
*nanus *Lapworth*, 1875
*nicholsoni *Lapworth* var. planus *Elles & Wood*, 1901
*nitidus (*Hall*), 1858
*patulus (*Hall*), 1858
pennatulus (*Hall*), 1858
perflexus *Gurley*, 1896
(?)rectus (*Emmons*), 1856
**sagittarius* (Hall), 1847
(=sagitticaulis)
*sagitticaulis *Gurley*, 1896
*serratulus (*Hall*), 1847
*similis (*Hall*), 1865
*spinosus *Ruedemann*, 1904
*subtenuis (*Hall*), 1877
cf. superstes *Lapworth*, 1876
**tenuis* (Hall), 1847
(=subtenuis)
*törnquisti *Ruedemann*, 1904
Graptolithus *Linné*, 1736
abnormis Hall, 1858
[*see* Clonog.]
alatus Hall, 1858
[*see* Tetrag.]

[1] In correction of the erroneous "ellesi."

Leptograptus flaccidus (*Hall*), 1865
mut. trentonensis *Ruedemann*, 1907
var. spinifer *Elles & Wood*, 1903
mut. trentonensis *Ruedemann*, 1907
mut. trifidus *Ruedemann*, 1907
Loganograptus *Hall*, 1868
*logani (*Hall*), 1858
Nemagraptus *Emmons*, 1856
**capillaris* Emmons, 1856
[*see* Thamnog.]
**elegans* Emmons, 1856
(=Nemag. gracilis)
*exilis *Lapworth*, 1896
var. linearis *Ruedemann*, 1907
*gracilis (*Hall*), 1847
var. surcularis *Hall*, 1868
var. crassicaulis *Gurley*, 1896
var. distans *Ruedemann*, 1907
var. approximatus *Ruedemann*, 1907
Phyllograptus *Hall*, 1858
*angustifolius *Hall*, 1858
*anna *Hall*, 1858
(?)cambrensis *Walcott* (*Gurley*), 1896
(?)*dubius* Spencer, 1884 (no graptolite)
*ilicifolius *Hall*, 1858
loringi *White*, 1874
**similis* Hall, 1858
(=Tetrag. similis)
simplex (*Emmons*) *Walcott*, 1889
(=P. cambrensis)
*typus *Hall*, 1858
Pleurograptus *Nicholson*, 1867
*linearis (*Carruthers*), 1858

Protograptus *Matthew*, 1885
alatus *Matthew*, 1885
Sigmagraptus *Ruedemann*, 1904
*praecursor *Ruedemann*, 1904
Staurograptus *Emmons*, 1856
*dichotomus *Emmons*, 1856
var. apertus *Ruedemann*, 1904
Stephanograptus Geinitz, 1866
(=Nemag.)
Syndyograptus *Ruedemann*, 1907
*pecten *Ruedemann*, 1907
Temnograptus *Nicholson*, 1876
*noveboracensis *Ruedemann*, 1904
Tetragraptus *Salter*, 1863
acanthonotus *Gurley*, 1896
alatus (*Hall*), 1858
*amii *Lapworth*, 1902
approximatus *Nicholson*, 1873
**bigsbyi* (Hall), 1863
(=T. similis)
*clarkii *Ruedemann*, 1904
crucifer (*Hall*), 1858
denticulatus (*Hall*), 1858
*fruticosus (*Hall*), 1858
headi (*Hall*), 1858
hicksi *Hopkinson*, 1875
*lentus *Ruedemann*, 1904
*pendens *Elles*, 1898
*pygmaeus *Ruedemann*, 1904
*quadribrachiatus (*Hall*), 1858
*serra (*Brongniart*), 1828
*similis (*Hall*), 1858
*taraxacum *Ruedemann*, 1904
*woodae[1] *Ruedemann*, 1904

[1] In correction of the erroneous "woodi."

Order 3 GRAPTOLOIDEA AXONOPHORA

Clathrograptus *Lapworth*, 1873
cuneiformis *Lapworth*, 1873
**geinitzianus* (Hall)
[*see* Retiog.]
Climacograptus *Hall*, 1865
**antennarius* Hall, 1865
[*see* Cryptog.]
antiquus *Lapworth*, 1873
*bicornis (*Hall*), 1847
**var.* peltifer *Lapworth*, 1876
**var.* tridentatus *Lapworth*, 1876
caelatus *Lapworth*, 1875
*caudatus *Lapworth*, 1876
var. laticaulis *Gurley*, 1896
?emmonsi *Walcott*, 1886
mississippiensis *Ruedemann*, 1907
*modestus *Ruedemann*, 1907
oligotheca *Gurley*, 1896
*parvus *Hall*, 1865
**phyllophorus* Gurley, 1896
(=parvus)
*pungens *Ruedemann*, 1904
*putillus (*Hall*), 1865
scalaris (*Hisinger*) var. annulatus *Ruedemann*, 1907
*scharenbergi *Lapworth*, 1876
*typicalis *Hall*, 1865
**mut.* spinifer *Ruedemann*, 1907
ulrichi *Ruedemann*, 1907
wilsoni *Lapworth*, 1876
Cryptograptus *Lapworth*, 1880
*antennarius (*Hall*), 1865
*tricornis (*Carruthers*), 1857
**mut.* insectiformis *Ruedemann*, 1907
Cyrtograptus *Carruthers*
ulrichi *Ruedemann*, 1907
Diplograptus *McCoy*, 1854
*D. amplexicaulis *Hall*, 1847
**var.* pertenuis *Ruedemann*, 1907
*angustifolius *Hall*, 1859
crassitestus *Ruedemann*, 1907
ciliatus Emmons, 1856
[*cf.* Glossog. ciliatus]
*dentatus (*Brongniart*), 1828
dubius Spencer, 1884 (no graptolite)
**eucharis* (Hall), 1865
[*see* Glossog.]
*euglyphus *Lapworth*, 1880
**var.* pygmaeus *Ruedemann*, 1907
dissimilaris Emmons, 1856
(=D. foliaceus)
*foliaceus (*Murchison*), 1839
**var.* acutus *Lapworth* ms, 1890
var. alabamensis *Ruedemann*, 1907
**var.* incisus *Lapworth* ms, 1890
var. trifidus *Gurley*, 1892
**mut.* vespertinus *Ruedemann*, 1907
foliosus Emmons, 1856
(=Lasiog.? sp. indet.)
hudsonicus *Nicholson*, 1875
hypniformis White, 1874
[*cf.* D. foliaceus]
*inutilis (*Hall*), 1865
**laciniatus* Emmons, 1856
(=D. foliaceus)
**laxus* Ruedemann, 1904
(=Cryptog. antennarius)
*longicaudatus *Ruedemann*, 1904
**marcidus* Hall, 1859
(=Cryptog. tricornis)
**mucronatus* (*Hall*), 1847
[*see* Lasiog.]
**obliquus* Emmons, 1856
(=D. foliaceus)

Lasiograptus *Lapworth*, 1873
*bimucronatus (*Nicholson*), 1869
**mut.* timidus *Ruedemann*, 1907
*mucronatus (*Hall*), 1847
Lomatoceras *Bronn*, 1834
(=Monog.)
Monograptus *Geinitz*, 1852
*beecheri *Girty*, 1895
*clintonensis (*Hall*), 1843
convolutus coppingeri *Etheridge*, 1878
elegans Emmons, 1856
(=Didymog. sp. indet.)
priodon *Bronn*, 1837
mut. chapmanensis *Ruedemann*, 1907
Rastrites *Barrande*, 1850
**barrandi* Hall, 1859
(=Thamnog. capillaris)
Retiograptus *Hall*, 1865
**barrandi* Hall, 1860
(=R. geinitzianus)
**eucharis* Hall, 1865
[*see* Glossog.]
*geinitzianus *Hall*, 1859
*tentaculatus (*Hall*), 1858
Retiolites *Barrande*, 1850
**ensiformis* Hall, 1858
[*see* Trigonog.]
*geinitzianus *Barrande* var. venosus (*Hall*), 1852
*R. *venosus* Hall, 1852
(=R. geinitzianus *var.* venosus)
Trigonograptus *Nicholson*, 1869
*ensiformis (*Hall*), 1858

INCERTAE SEDIS

Chaunograptus *Hall*, 1879
*gemmatus *Ruedemann*, 1907
gracilis *Clarke*, 1907
novellus *Hall*, 1879
*(?)rectilinea *Ruedemann*, 1907
Corynoides *Nicholson*, 1867
*calicularis *Nicholson*, 1867
*gracilis *Hopkinson*, 1872
**mut.* perungulatus *Ruedemann*, 1907
*curtus *Lapworth*, 1876
**mut.* comma *Ruedemann*, 1907
Dawsonia *Nicholson*, 1873
acuminata *Nicholson*, 1873
campanulata *Nicholson*, 1873
*monodon *Gurley*, 1896
rotunda *Nicholson*, 1873
tenuistriata *Nicholson*, 1873
*tridens *Gurley*, 1896
Protovirgularia *McCoy*, 1851
**cf.* P. dichotoma (*McCoy*) *Gurley* ms, 1907
Strophograptus *Ruedemann*, 1904
*trichomanes *Ruedemann*, 1904

REJECTED AS GENERA OR AS GRAPTOLITES

Bythograptus *Hall*, 1861
(No graptolite)
Caryocaris *Salter*, 1863
(No graptolite)
*curvilatus *Gurley*, 1896
oblongus *Gurley*, 1896
wrightii *Salter*, 1863
Megalograptus *Miller*, 1874
(No graptolite)
Phycograptus *Gurley*, 1896
*brachymera *Gurley*, 1896
*laevis (*Hall*), 1847

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[1] This list is supplementary to that given in part 1 and mainly gives references of publications bearing on the higher graptolite faunas of North America here dealt with.

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[a] Part 5 (genus Climacograptus) did not come to hand until the completion of this memoir and for this reason has not been fully available.

DESCRIPTION OF GRAPTOLITES

Order I DENDROIDEA Nicholson

Family DENDROGRAPTIDAE Roemer.

DENDROGRAPTUS Hall

See N. Y. Nat. Mus. Mem. 7, p.578

Dendrograptus rectus sp. nov.

Plate 8, figure 2

Description. Rhabdosome bearing numerous, subparallel branches of rigid appearance which bifurcate frequently and at very acute angles; the latter being smallest in the distal bifurcations (5°–10°, and about 70° in the basal portions). The type, an imperfect specimen, is 61 mm long and 45 mm wide; its branches are 7 mm wide in the lateral view. The latter exhibits rows of prominent thecae which are all turned toward the inside of the rhabdosome, and to the naked eye seem acutely pointed. Enlarged, they are found to overlap about one half their length, diverge at 10° from the axis of the branch and possess tonguelike projecting outer apertural margins and concave, notched lateral apertural margins. The thecae number 14 in 10 mm.

Fig. 51 Dendrograptus rectus sp. nov. Fragment, showing thecae in profile view. x 5

Position and locality. In the dark greenish gray Clinton shale, overlying the lower ore bed at Clinton, Oneida co., N. Y.

Remarks. This form bears no similarity to any of the Siluric Dendroidea, but reminds one in the character of its thecae of some of the earlier species, as D. fluitans from the Beekmantown shales, and in its general habit it approaches most nearly to two other Beekmantown forms, viz, D. fruticosus and D. gracilis. With these it apparently belongs to the small group, which with the genotype will, after the final splitting up of the genus, be left in Dendrograptus s. str.

CALLOGRAPTUS Hall

See N. Y. State Mus. Mem. 7, p.583

Callograptus compactus (Walcott)

Plate 1, figure 1

Dendrograptus compactus Walcott. Albany Inst. Trans. 1881. 10: 21, pl. 1, fig. 1

Dendrograptus compactus Gurley. Jour. Geol. 1896. 4: 94

Description. Rhabdosome of small size (length of largest specimen observed 40 mm), consisting of a basal disk with a short stem (5 mm) and the frond which is probably infundibuliform. The branches assume at once a subparallel direction, are straight or gently undulating, .3 mm–.4 mm wide, separated by intervals twice their width and connected by widely separated dissepiments. The thecae are rather indistinct and but little projecting, without apertural appendages, of composite character and numbering 12–14 in the space of 10 mm.

Fig. 52 Callograptus compactus (Walcott). Fragment of branch showing form of thecae. x 5

Position and localities. This species has thus far been found only in its type locality, i. e. in the Utica shale at Holland Patent, Oneida co., N. Y.

Remarks. Walcott has described the form as fan-shaped[1] but the crowding and overlapping of the branches on one side of the frond in the specimen here figured suggests the possibility of an original infundibuliform shape. The basal disk is stout, of irregular shape and outline and shows obscure marginal lappets. The general form of the rhabdosome, especially the subparallel arrangement of the branches, and their connection by a few scattered dissepiments, are characters of Callograptus, apparently not shown in the type of the species which according to Walcott is much weathered. Although the original diagnosis of Callograptus calls for "flabellate fronds," this statement is qualified in the last supplementary remark [Hall, 1865, p.133], and the probable infundibuliform shape of this species is not antagonistic to its reference to that genus.

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[1] The original description is: Frond fan-shaped; branches comparatively coarse and numerous; stipe below the branches unknown.

PTILOGRAPTUS Hall

We have already noted this genus in part 1 of this work [Mem. 7, p.587] on the occasion of the description of three species from the Deepkill shales. We add here two more species which differ so markedly in the character of their thecae as to invite further remarks.

Wiman described in 1895 [p.63] the internal structure of a form that he referred to Ptilograptus (P. suecicus). This welcome information on Ptilograptus has been withdrawn, the species now being apparently quite correctly placed by the same author under Inocaulis [1900, p.191].

That the genus Ptilograptus which now again is based only on the plumose arrangement of its branches, has as complex an internal structure as has been found in other Dendroidea that have been studied by means of etched specimens, is quite evident from several facts, as the distinct presence of pores, other than the apertures of the large thecae [*see* text fig. 53] and the fibrous and ropelike appearance of the branches of others [*see* Počta's P. glomeratus and P. ramale].[1]

Ptilograptus, as now defined by the habitus of the rhabdosome alone, comprises quite obviously two different groups of forms, the same as Dendrograptus [*see* Mem. 7, p.578], viz, those with smooth branches and impressed thecal apertures and those with prominent "denticles." The former is characteristically represented by the genotype, P. plumosus, and the Bohemian forms, the latter by the species here described and by P. acutus Hopkinson. That this difference in external character is indicative of fundamentally distinct structures is shown by the writer in this memoir in the cases of Dendrograptus s. str. and Mastigograptus.

The first of the species here described possesses in the tonguelike processes of the apertures, a feature distinguishing it from all its congeners. These have a similar form and like position as the dissepiments of certain Dictyonemas (e. g. D. cervicorne and D. cavernosum). Whether they actually served as dissepiments thereby making of the pretty

[1] This and other species of Ptilograptus, described by Počta [1894] were unfortunately overlooked by the writer in commenting on the species of that genus in Memoir 7.

little rhabdosome a perfect network, recalling in form the veination of a leaf, or whether they are the remains of long conical or tubular capsules like the appendages of Mastigograptus tenuiramosus is unfortunately left uncertain by the material.

Ptilograptus poctai sp. nov.

Plate 1, figure 8

Description. Rhabdosome of unknown size; fragment 10 mm long, consisting of flatly zigzagged stem and closely arranged (5 in 5 mm), obliquely ascending (50°), somewhat flexuous branches which are 7+ mm long and .3 mm thick. Stem and branches distinctly composed of slender thecae which strongly project from the branch (angle of inclination 30°), are four times as long as wide, overlap a little more than one fourth their length and number 12 in 10 mm. Their ventral margin is straight, the apertural margin slightly concave and normal to the axis of the theca. From its ventral rim a tonguelike, terminally notched process proceeds that is about half as long as the theca; sicula and basis have not been observed.

Fig. 53 Ptilograptus poctai sp. nov. Enlargement (x 5) of type specimen

Position and locality. A single specimen has been found in the Normanskill shale at Glenmont, Albany co., N. Y. where it is associated with Dicranogr. nicholsoni var. diapason.

Remarks. From the species of Ptilograptus which we have recorded from the Deepkill shale, this type is easily distinguished. It stands in the middle between P. plumosus and P. geinitzianus in thickness and size of branches and differs markedly from both by the prominent denticles and the apertural processes of its thecae. Its strong denticulations it has in common with P. acutus Hopk., a form of the Welsh Lower Llandeilo, which has received its name from its acutely pointed denticles. It resembles the latter form also in its habit, as far as the fragmentary character of our specimen permits to judge, but is of smaller size and more delicately

built. In its general appearance it also recalls two Bohemian forms, viz, P. ramale and glomeratus Počta, both from Dd3 and hence of approximately equal age. These, however, do not show any prominent thecae, but instead exhibit a distinctly fibrous structure of the branches.

Ptilograptus hartnageli sp. nov.

Plate 1, figure 9

Description. Frond very delicate (branch and branchlets not more than .2 mm wide). Branch (probably not quite complete) 7 mm long, distinctly zigzagged; branchlets (pinnules) about 4 mm long and diverging from the branch at 40°. There are five of them counted on either side of the branch in the fragment. The thecae are quite distinct, their ventral margin diverging about 20° from the axis of the branchlet; they are conical; overlap about one quarter their length, possess straight or slightly convex ventral margins and straight dorsal margins and number 16 to 17 in 10 mm.

Fig. 54 Ptilograptus hartnageli sp. nov. Enlargement (x 10) of type specimen

Position and locality. One specimen collected in greenish-gray Clinton shale above the iron ore at Sterling station, Cayuga co., N. Y. by Mr C. A. Hartnagel.

Remarks. The specimen while beautifully preserved in its details, is clearly but a fragment of a larger rhabdosome. From the only other Siluric congener on this side of the Atlantic, P. foliaceus Spencer from the Niagaran of Hamilton, Ontario, it is easily distinguished by the greater slenderness of its branches and branchlets and the longer and less overlapping thecae, which in the Niagaran form number 20 in 10 mm.

DICTYONEMA Hall

See N. Y. State Mus. Mem. 7, p.591

Dictyonema neenah Hall

Dictyonema neenah Hall. Sup't Geol. Sur. Wis. Rep't Prog. 1861. p.7

Dictyonema neenah Whitfield. Amer. Mus. Nat. Hist. Mem. 1895. v. 1, pt 2, p. 47, pl. 5, fig. 13

Dictyonema neenah Počta. Syst. Sil. Bohême. 1894. vol. 8, t. 1, p.193

Dictyonema cf. neenah Gurley. Jour. Geol. 1896. 4: 81

Dictyonema neenah Gurley. *Ibid.* p.300

Original description. Frond spreading, infundibuliform, reticulate, the radiating branches slender, direct, a very little undulating, the transverse connecting filaments more slender than the branches: reticulations quadrangular or oval, the length from one and a half to twice the width; from six to seven and a half in the space of half an inch, and transversely from 12 to 14 in the same distance. Serrations or cellules not determined.

This species is deeply funnel-shaped, the branches but slightly diverging and the intercalated or implanted branches at distant intervals. The matrix is a compact granular limestone, a substance unfavorable to the preservation of the cellules or of the finer markings of the surface.

In the form and proportions of the cellules and the greater proportional width of the connecting filaments, this species differs from any of those described.

Geological formation and locality. In the Trenton limestone of the Fox river, near Appleton, Wisconsin. I am indebted to Prof. R. Z. Mason, of the Appleton University, for the specimen.

Dr Gurley annotates this form in his manuscript as follows:

Hall's description and Whitfield's figure cover all essential points. Branches about 30 in 25 mm, 0.3–0.4 mm wide. The dissepiments are mostly 12–16 in 25 mm; usually stouter than the branches, ranging from 0.4 to 0.8 mm. They are usually biconcave, widening as they approach the branches, thus giving the mesh an elliptic form. The tendency of the dissepiments to extend across many branches at the same level (producing a banded appearance) is pronounced. The infundibuliform aspect of the polypary is perfectly evident, the whole lower half being clearly traceable distally under a thin "cliff" of the rock. Though very distinctly defined the branches and dissepiments are only preserved as stains, and no thecae are anywhere visible.

The most striking features of this species are the great width of the dissepiment, their biconcavity and tendency to occur at regular levels forming continuous broad dark bands across the surface.

Dictyonema obovatum Gurley

Dictyonema obovatum Gurley. Geol. Sur. Ark. Rep't. 1890. 1892. 3:418
Dictyonema obovatum Gurley. Jour. Geol. 1896. 4:300

We have been unable to find the type of this species, in the collection of the National Museum from the Lower Dicellograptus zone of the type locality "near Crystal Springs, Arkansas." The species avowedly is based upon but one specimen and this has been described but not yet figured.

Dictyonema spiniferum sp. nov.

Plate 1, figure 4

Description. Entire rhabdosome not observed. Fragments of rhabdosome (40 mm long) consisting of subparallel, straight or but slightly irregularly bending branches; .3–.4 mm wide and separated by an interval that is not at all or but little greater. Dissepiments frequent and stout, forming with the branches rectangular meshes, mostly 3 mm long. The thecae are prominent, inclined at 30° and number 14 in 10 mm; their apertures are normal, and furnished with a very acute, horizontal spine about as long as the aperture.

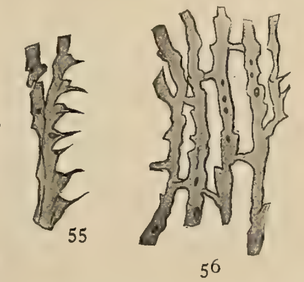

Fig. 55, 56 Dictyonema spiniferum sp. nov. Fig. 55 Enlargement of branch showing the thecae in profile view. Fig. 56 Enlargement of fragment of rhabdosome showing form of meshes. x 5

Position and locality. Of this species but three specimens have been collected in the Normanskill shale at Glenmont, near Albany; each in other association, viz, with Dicellograptus gurleyi, Diplograptus foliaceus and D. angustifolius.

Remarks. From the associated dendroid graptolites this form is readily distinguished by its close meshwork and the prominence and distinct spinosity of the thecae. In the form of the thecae and its general habitus it recalls D. furciferum, a Beekmantown shale graptolite.

Dictyonema arbuscula (Ulrich)

Dictyonema irregulare (Hall) James. The Palaeontologist. 1879

Inocaulis arbuscula Ulrich. Cin. Soc. Nat. Hist. Jour. 1879. 2:28, pl. 7, fig. 27, 27a

Dictyograptus reticulatus (*nomen nudum*) Ulrich. Cat. Foss. Cincinnati group 1880. p.61

Inocaulis arbuscula Ulrich. *Ibid.*

Calyptograptus ? arbusculus Spencer. Acad. Sci. St Louis Trans. v. 4 (bull.) 1884. p.563

Dictyonema arbusculum Gurley. In J. F. James, Cin. Soc. Nat. Hist. Jour. 1892. p.153

Inocaulis arbuscula Gurley. Jour. Geol. 1896. 4: 300

Dictyonema arbusculum Nickles. Cin. Soc. Nat. Hist. Jour. 1902. 20: 72

Description. Rhabdosome small (15+ mm), flabellate or infundibuliform, rapidly expanding by successive bifurcations, the branches diverging from 60°-70°, narrow (.3 mm), gently undulating or curvilinear in direction in the proximal portion, forming long oval meshes, principally by contact, but becoming straighter more distally and then probably forming dissepiments. Thecae projecting, forming distinct denticles, numbering about 13 in 10 mm. Sicula not observed.

Fig. 57, 58 Dictyonema arbuscula (Ulrich). Fig. 57 Copies of original drawings. Fig. 58 Enlargement (x 5) of authentic specimen. Original in Ulrich collection

Position and locality. Ulrich records it from the Middle third of the Eden shale at Covington, Ky. and Nickles in his "Geology of Cincinnati" [*loc. cit.*] lists it as a fossil of the middle Utica or Batostoma jamesi beds.

Remarks. This species has been twice described, first by Ulrich [1879], who noted the presence of the denticles, and then by Gurley [1892], who recorded the curvilinear direction of the branches and the presence of dissepiments. We figure here an enlargement of a well preserved specimen (metatype) of the Ulrich collection from which we have obtained the above given diagnosis. The specimens give the impression of being but the proximal portions of larger rhabdosomes for they

exhibit the characteristic close initial branching which in Dictyonema later is followed by straighter and less divided branches. Our specimen does not show any undisputable dissepiments and is more suggestive of a Desmograptus, but on the supposition that it is but a proximal fragment, the absence or scarcity of dissepiments is in line with other species of Dictyonema [*see* Mem. 7, p.602]. The thecae have a straight outer margin and do not seem to possess any apertural appendages.

Dictyonema pertenue Foerste

Dictyonema pertenue Foerste. Sci. Lab. Denison Univ. Bul. 1887. 2: 107, pl. 8 (pl. 8 was issued in v. 3)

Dictyonema pertenue Foerste. Geol. Sur. O. Rep't. 1893. 7: 600, pl. 27, fig. 27a, b

Dictyonema pertenue Gurley. Jour. Geol. 1896. 4: 308

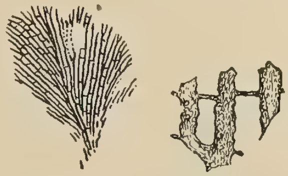

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Fig. 59, 60 Dictyonema pertenue Foerste. Copies of original figures

We have not seen any material of this species and the latter has been so elaborately described by its author that little could be added by further investigation. The form is evidently a good species and distinctly separated from its Clinton congeners by its finer structure.

Dictyonema scalariforme Foerste

Plate 1, figure 3

Dictyonema scalariforme Foerste. Sci. Lab. Denison Univ. Bul. 1887. 2: 108, pl. 8, fig. 28, 29 (pl. 8 issued in v. 3)

Dictyonema scalariforme Foerste. Geol. Sur. O. Rep't. 1893. 7: 600, pl. 27, fig. 28, 29

Dictyonema scalariforme Gurley. Jour. Geol. 1896. 4: 308

Mr Hartnagel has collected a representative of this species in the red ferruginous shale accompanying the iron ore of the Clinton beds, east of Clinton village, N. Y. Professor Foerste has furnished the following elaborate description of D. scalariforme:

Frond infundibuliform. Branches of medium size, from once to twice their own width distant from each other, dividing dichotomously and connected by transverse bars or dissepiments one fourth or one third their width. The dissepiments are stationed at unequal distances from each

other, varying from once to twice the distance between the branches, and leaving quadrangular or oblong fenestrules between the same. The celluliferous side of the frond has not been seen; in places however where the frond has been abraded the position and the frequency of the cells is distinctly shown. Judging from this, they are placed in a single row along the middle of each branch; there are about 13 cells in a length of 5 mm. These cells seem to have an oblique upward direction, consecutive cells leaning upon those in front of them, thus forming a narrow ridge or keel; at their tips the cells seem to have become more or less free, and to have developed circular apertures. Noncelluliferous face striated obliquely by short, curved striae suggesting twisted strands.

Frond here described, a flabellate fragment, 40 mm long and 35 mm broad. From 10 to 12 branches occupy a width of 10 mm and from 10 to 15 dissepiments occupy the same distance in length. The branches where they are well preserved, are from .5 mm to .65 mm wide. The dissepiments vary from .1 mm to .22 mm in thickness.

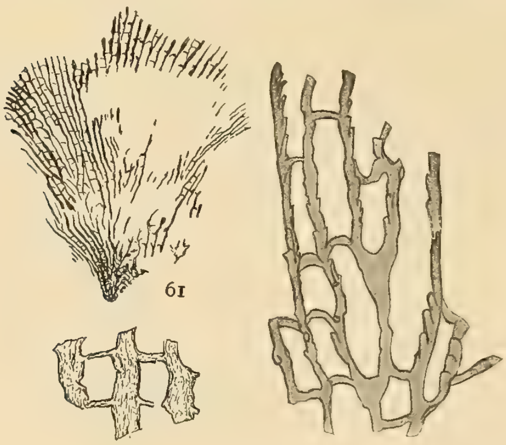

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Fig. 61, 62, 63 Dictyonema scalariforme Foerste. Fig. 61, 62 Copies of original figures. Fig. 63 Enlargement (x 5) of portion of specimen from Clinton, N. Y.

The name signifies *ladder-shaped.*

This species is evidently related to Dictyonema retiforme Hall, differing from the same in the narrower branches being more compactly arranged, the dissepiments likewise occurring at shorter intervals. According to Prof. J. W. Spencer the branches of D. retiforme are on an average about 1 mm in width. The largest branches of our specimens do not attain this width.

Locality and position. Soldiers home [Dayton, O.], Clinton group.

Graptolites of this genus usually appear as black strands on the surface of the rock. In this connection it is interesting to note that the cell walls of Stictopora gracilis Spencer present the same appearance, momentarily suggesting a graptolite.

Remarks. Our Clinton specimen is a basal fragment or young colony; it has 10 to 12 branches in the space of 10 mm; its dissepiments are not very well preserved, but where seen but 1 mm apart, and the branches are in the average .5 mm wide. The thecae number 11–13 in 10 mm and are slender, distinctly projecting, overlap apparently about one half and possess

straight or slightly convex ventral and gently concave apertural margins; they are apparently without apertural appendages.

The specimen from our Clinton beds suggests in its habitus relationship to D. gracile more than to any other form; in fact the differences between D. scalariforme and D. gracile are so minimal as a comparison of their dimensions will show that a close relationship between the two can not be doubted. Their main differences would seem to rest in the smaller size of the rhabdosome and the closer arrangement of the dissepiments in D. scalariforme. The latter difference is more or less invalidated by the fact that also in portions of D. gracile the dissepiments approach each other sometimes to 1 mm. A third form which is closely related to both of these species, according to its dimensions, is D. venustum Lapworth [1881], which, moreover, is of the same period. The present species stands nearest to the Scottish form but still differs in the closer arrangement of the dissepiments.

In our Clinton shale D. scalariforme is associated with Palaeodictyota clintonensis.

Dictyonema retiforme Hall

Plate 3, figure 1

Gorgonia ? retiformis Hall. Geol. N. Y. 4th Dist. 1843. p.115, fig. 1

Dictyonema retiforme Hall. Am. Jour. Sci. 1851. 11: 401

Dictyonema retiforme Hall. Pal. N. Y. 1852. 2: 174, pl. 40F, fig. 1a, 1b

Dictyonema retiforme Hall. Can. Org. Rem. Dec. 2. 1865. p.12, fig. 10

Dictyonema retiforme Hall. N. Y. State Cab. Nat. Hist. 20th Rep't. 1868. p.178, fig. 11

Dictyonema retiforme Hall. *Id.* rev. ed. p.210, fig. 11

Dictyonema retiformis Spencer. Can. Nat. 1878. 8: 458

Dictyonema retiforme Spencer. Can. Nat. 1882. 10: 165

Dictyonema retiforme Lesquereux. Geol. Sur. Ind. 13th Rep't. 1883. p.30

Dictyonema retiforme Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 573, 574, pl. 3, fig. 1, 2

Dictyonema retiforme Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 14, 23, 24, pl. 3, fig. 1, 2

Dictyonema retiforme Miller. N. Am. Geol. Pal. 1889. p.185, fig. 168

Dictyonema retiforme Gurley. Jour. Geol. 1896. 4: 96, 308

Dictyonema retiforme Počta. Syst. Sil. Bohême. 1894. 8: 192, 193

Dictyonema retiforme Frech. Lethaea Pal. 1897. 1: 575, fig. 145

Dictyonema retiforme Grabau. N. Y. State Mus. Bul. 45. 1901. p.134, fig. 27

Dr Gurley has furnished in his manuscript, from the types and other specimens, the following redescription of this form, which is important as being the genotype of Dictyonema:

Polypary rather strongly radiate, with the branches usually about 0.8 mm wide (a few as narrow as 0.6 mm, a few swelling out to 1 mm, particularly immediately below a bifurcation); about 15–17 in 25 mm of width, in the basal portion, and in young specimens frequently somewhat more slender, more tortuous (with slight tendency to zigzag) and somewhat farther apart; the interspaces consequently as wide as, or slightly wider than, the branches. Dissepiments mostly transverse (some are slightly oblique, a few very oblique); generally slender (about 0.2 mm), but a few reach 0.3 mm or rarely 0.4 mm. Meshes mostly oblong; a number of careful measurements has shown me that the most usual (the typical) length is on the average 1.5 mm (between 1 and 2 mm), but longer ones are seen, from covering up or destruction of the intervening dissepiments, which condition in favorable cases can be proven. Rarely two successive dissepiments are not farther apart than 0.5 mm. This almost invariably results from the two dissepiments diverging from a common point of origin on one branch.

Fig. 64 Dictyonema retiforme Hall. Enlargement (x 5) of portion of specimen from the Rochester shale at Lockport, N. Y. Note the crossing dissepiments at the left

Position and locality. In New York this form is found in the Rochester shale, principally between Rochester and Niagara Falls. It occurs also in the Lockport limestone at Hamilton, Ontario, and Frech cites it also (probably erroneously) from Missouri. Its types are in the American Museum of Natural History.

It is by no means so common in our Niagara beds as one should suspect from its long bibliographic list or conclude from the direct statement

of some authors that it is abundant in the New York rocks; in fact it is one of the least common of the graptolites of our Rochester shale and all the references are excerpts of Hall's original description. I have seen altogether not more than half a dozen specimens, including Hall's types, and have not been able to find one which would reveal the form of the thecae.

Remarks. D. retiforme is a remarkably stately graptolite, possessing wide open funnel-shaped rhabdosomes, fragmentary specimens of which with a diameter of no less than half a meter have been observed; and the size of the branches and the meshwork are coarse in proportion. Pocta has compared it to the Bohemian D. grande Barr., also a Siluric form and pointed out the differences between the two.

Gurley remarks that "Hall's enlargements [1852, pl. 40F] are taken from an entirely different species (either D. expansum or C. subretiforme)," but since in the earlier time all enlargements were free-hand drawings and often more diagrammatic than accurate, we believe that these enlargements are actually taken from D. retiforme, and add here a camera enlargement of our own to give a more correct conception of the details of this species.

Dictyonema gracile Hall

Plate 1, figure 5

Gorgonia ? Hall. Geol. N. Y. 4th Dist. 1843. p.115, fig. 42 (right hand figure)
Dictyonema gracile Hall. Pal. N. Y. 1852. 2: 175, pl. 40, fig. 1a–1d
Dictyonema gracile Rominger. Geol. Sur. Mich. 1873. v. 1, pt 3, p.44
Dictyonema gracile Lesquereux. Geol. Sur. Ind. 13th Rep't. 1883. p.30
Dictyonema gracile Počta. Syst. Sil. Bohême. 1894. v. 8, t. 1, p.193
Dictyonema gracile Gurley. Jour. Geol. 1896. 4: 308

Dr Gurley gives the following careful redescription of this species after its two type specimens in the American Museum of Natural History in New York city.

Branches about 27 (25–30) in 25 mm, only moderately diverging, very straight, (hardly at all flexuous), bifurcating at intervals of 10 to 20 mm, with rounded angles; very uniformly 0.4 mm in diameter, subparallel. Dissepiments exceedingly delicate, and apparently unusually remote (2 to 3 or 4 mm), but in some places intermediate ones can be detected at intervals of

about 1 mm. At the same time these are not so frequently visible as to warrant an assertion that this minimal distance is the usual one, and the material, slightly worn, as it is, leaves me in some doubt on the point. In several places a few thecae can be seen, apparently set about 50 in 25 mm. The branches near the base are thicker (0.6 mm) in number about 25 in 25 mm.

Position and localities. Hall stated that this species occurs only in the shale at Lockport, N. Y. Newer collections by the State Museum show that, in some outcrops of the Rochester shale, it is a very common form, as for instance at Middleport, N. Y., where it is associated with Palaeodictyota anastomatica. Spencer has also recorded it from the Lockport limestone at Hamilton, Ontario and Rominger cites it from the Manistique river, Michigan.

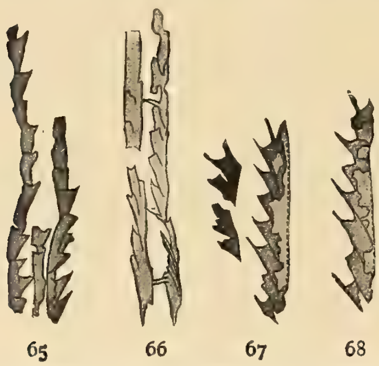


Fig. 65–68 Dictyonema gracile Hall. Fragments showing different aspects of the thecae; figure 66 also dissepiments. Original of figure 66 is from the Niagaran limestone at Hamilton, Ont.; those of the others are from the Rochester shale at Middleport, N. Y. x 5

Remarks. Some excellently preserved material, obtained at Middleport, allows us to add the following data to the above given description. The rhabdosome was cyathiform, expanding at a medium rate and attained considerable size, one fragment having a length of 14 cm. In one (young ?) specimen a short basal stem (2 mm long) and a small adhesion disk are seen. The thecae are not as closely arranged as Gurley concluded, they number but 13–14 in 10 mm; they are quite prominent, their angle of divergence being 30°, and overlap almost one third their length; their ventral margin is straight, the apertural margin very concave, the denticle acute and ending in a mucro.

Dictyonema polymorphum Gurley ms

Plate 2, figure 3; plate 3, figures 4, 5, 6

Dictyonema tenellum Spencer. Acad. Sci. St Louis. Trans. 1884. v. 4, pl. 1, fig. 13 (not the description. p.576)

Dictyonema tenellum Spencer. Mus. Univ. State Mo. Bul. 1884. v. 1, pl. 1, fig 13 (not the description, p.26)

Calyptograptus subretiformis (pars) Spencer. Acad. Sci. St Louis. Trans. 1884. v. 4, pl. 4, fig. 2

Calyptograptus subretiformis (pars) Spencer. Mus. Univ. State Mo. Bul. 1884. v. 1, pl. 4, fig. 2

Dictyonema polymorphum Gurley ms

The Rochester shale at Middleport, N. Y. has furnished us a considerable number of specimens of a form which by comparison with Gurley's type has been found to be identical with the above cited species. The latter has, as shown by the above given bibliography which is taken from Gurley's manuscript, been partly described as D. tenellum and partly as Calyptograptus subretiformis. We insert here Gurley's elaborate description of this species which is accompanied by two drawings [pl. 3, fig. 5, 6] made under his supervision, the first of which, being cited by Gurley in the manuscript, is to be considered as representing the type, the other as a cotype.

Polypary originally cyathiform, circular or flabellate on the rock, when flabellate often evenly semicircular in the largest specimen seen, 85 mm in diameter; originating in, and sessile upon a carbonaceous "disk," which in one specimen is seen to have its walls riddled with pores. Branches measuring 0.6 mm in width on the average, hardly ever as narrow as 0.3 mm (as Spencer states them to average), 0.4 mm being with rare exceptions, the minimum; and 0.8 the maximum. Branches varying equally in character, being sometimes nearly straight, at others irregularly sinuous, and inosculating as in *Desmograptus*. Occasionally the adjacent margins of two branches coalesce. The branches end in long drawn out, spikelike points. Very often — usually in fact — shortly before their termination, they bifurcate U-like, the termination thus being forcepslike. This mode of ending is quite characteristic of the species. Apparently this spikelike forking of the branches may occasionally take place in the wall of the polypary below the summit, and the spikes then seem to serve the same purpose as dissepiments bracing the polypary. As the fossil usually lies on the stone, the number of branches in 25 mm of width is exceedingly variable, generally from distortion. In places where the polypary is evenly and smoothly laid out and the meshwork perfectly regular, however, the number is about 22 (20–25) near the base and about 25–30 at the periphery. The dissepiments are of medium thickness (about 0.15–0.4 mm) and are either perpendicular or highly inclined (say 45°) to the branches, and this combination in the same specimen forms a striking feature of this species, a feature well shown

in Spencer's figure. Meshes very variable in shape, corresponding to the irregularity in the branches and dissepiments. In the specimen [pl. 3,

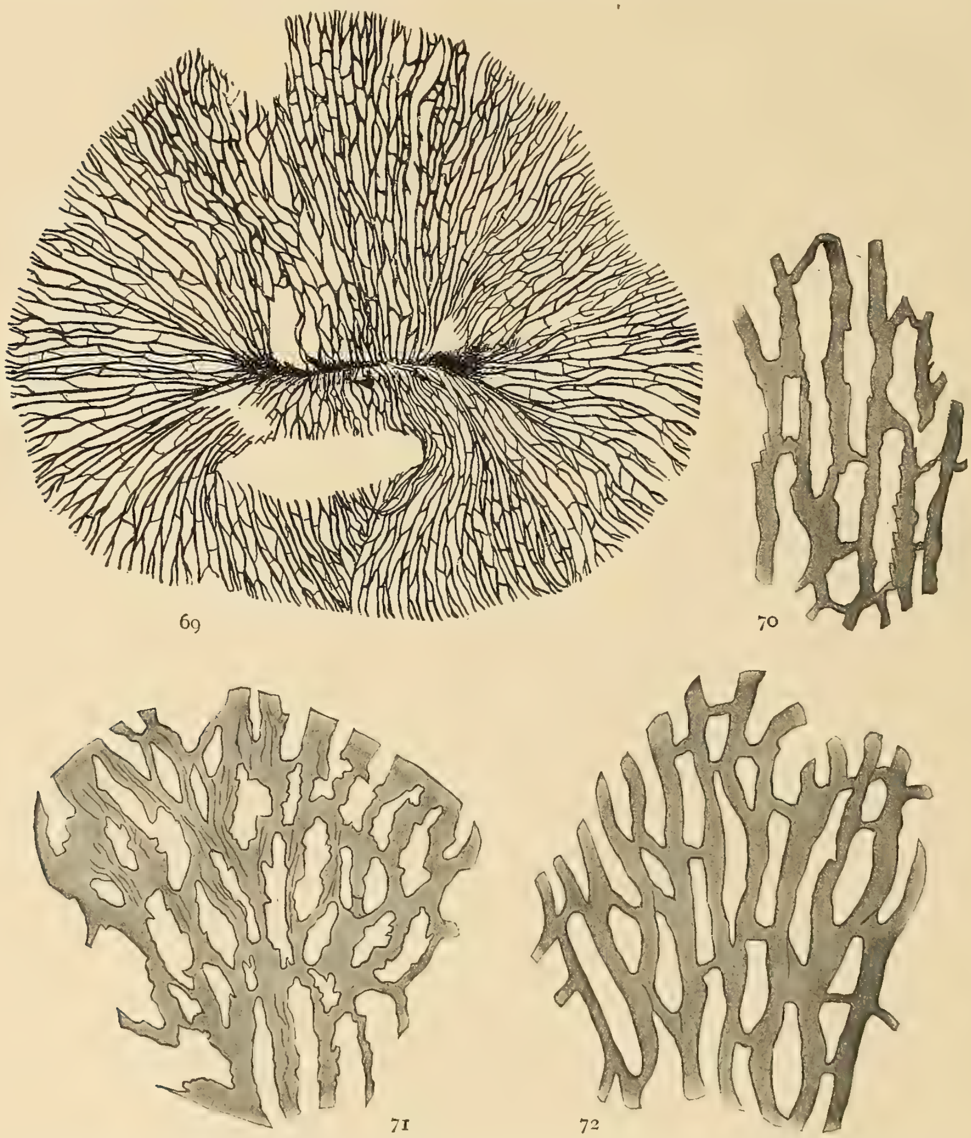


Fig. 69–72 Dictyonema polymorphum Gurley ms. Fig. 69 Copy of Spencer's drawing of D. tenellum cited in the text as representing D. polymorphum. Fig. 70 represents a proximal, fig. 71 a more distal portion of a rhabdosome, both from the same slab (from Hamilton, Ont.); fig. 72 is the enlargement of a fragment of the type. x 5

fig. 5] I find meshes from 1.5 to 6 mm long, but the longest are in one or two cases demonstrably subdivided and probably 3 mm is about the greatest

length. From obscure indications the thecae seem to be set about 50 in 25 mm (Spencer gives the number as 60).

One specimen [pl. 3, fig. 6] in the Hall collection shows the base fairly well preserved. This measures about 12 mm by 8 mm and shows a unique structure. The margin is in places sharply defined, and is either convex or concave. The surface is uniformly dotted with very numerous elliptic or circular pores, which hardly reach 0.2 mm in greatest diameter, and which have a well defined rimlike margin. They seem to have a somewhat regular arrangement in rows and are separated by interspaces narrower than their own diameter. The texture of this "disk" like that of the network, is carbonaceous.

Horizon and locality. Twenty-four specimens from the Niagara chert and glaciated chert beds, Hamilton, Ontario.

In this count are included two specimens in the Spencer collection, labeled "Calyptograptus subretiformis." While these two specimens are very poor, still without question they belong here and not with C. subretiformis. On the other hand, it is quite evident to me that these two specimens are of the species which furnished the basis for Spencer's figure 2, which differs considerably from his figure 1, and his figure 2 should therefore, I believe, be added to the synonymy of D. tenellum.

This species is exceedingly variable in appearance. It is sometimes spread out circularly, sometimes flattened flabelliformly from the side. Its most characteristic features are the average thickness of 0.6 mm (not 0.3 mm, as Spencer's text states), their number of 20–25 in 25 mm of width in the proximal, and of 25–30 in the distal portion of the polypary. But in this species more than in others, it is possible to get almost any number, unless the place for counting be carefully chosen, where the meshes are regularly laid down and not distorted. Further, the combination in the same specimen of transverse dissepiments and of dissepiments inclined at about 45° to the branches, with, in other places, modes of connection (coalescence of approximated lateral margins, curving together and entire fusion of adjacent branches) usual in *Desmograptus*, thus producing a great variety of mesh form, constitutes a striking feature in the present species.

Remarks. In the Rochester shale at Middleport this is one of the most common graptolites. It attains there considerable size, patches indicating a diameter of 22+ cm of the rhabdosome when flattened to a circle, being found. Smaller fragments of the same form have also been noticed at the base of the Rochester shale, directly above the Clinton shale at Palmer's glen, near Rochester and the collection of the National Museum

contains a fragment from the Rochester shale at Lockport. This form is easily distinguished from both its associated congeners, D. retiforme and D. gracile by its more irregularly bent branches and the oblique direction of the dissepiments. By these characters it seems to lead directly to Calyptograptus subretiformis Spencer with which it is also associated.

The thecae have not been seen in full profile in any of our specimens.

On account of the interest which this form has gained as one of the more common graptolites of the Rochester shale, we insert here the figure of D. tenellum Spencer, referred by Gurley to D. polymorphum, since it represents a complete specimen, and camera enlargements of Gurley's type [fig. 72] and of material from Middleport, N. Y.

Dictyonema subretiforme (Spencer)

Plate 2, figures 1, 2

Calyptograptus subretiformis Spencer. Can. Nat. 1878. 8: 458, 460

Calyptograptus subretiformis Spencer. Can. Nat. 1882. 10: 165

Calyptograptus subretiformis Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 578, 579; pl. 4, fig. 1 (not figure 2)

Calyptograptus subretiformis Spencer. Mus. Univ. State Mo. Bul. 1884. 1:24, 28, 29; pl. 4, fig. 1 (not figure 2)

Calyptograptus subretiformis Gurley. Jour. Geol. 18. 4: 93, 308

Several good specimens of this species, one a complete colony, were obtained in the Rochester shale at Middleport, N. Y. Spencer's original description of the species as it occurs in the Niagara limestone at Hamilton, Ontario, is:

Frond circular, but cyathiform in its growing state. There are numerous bifurcating branches, which in the fossil condition imperfectly unite or overlie each other producing a kind of fine network with irregular subrhomboidal [ellipsoidal, 1884] interstices. In texture it is corneous, having the branches marked with striations of a subrhomboidal form.

In this species the branches are much finer (but little more than 1/80 inch in width, 0.35–0.75 mm, 1884) than in C. cyathiformis, with more numerous and irregular bifurcations, producing a netted appearance. The original matter is often replaced by pyrites. The fronds are not generally more than 2 inches in diameter. Only a few specimens have been found, and these show some varietal differences.

This species was found in the Niagara limestone [principally in the shaly dolomite beneath the chert bed, 1884], Hamilton, Ontario, by Colonel Grant.

Gurley adds the following data to Spencer's description:

Measurements of a number of branches show that these nearly all fall between 0.4 mm and 0.6 mm, 0.4–0.5 being the dimensions usual in the distal portion for the branches exclusive of the terminal twigs. The more proximal stems measure 0.6 mm, and the thickest seen (in one specimen only) reached 0.8 mm. Corresponding to the straggling aspect of this species almost any number of branches may be counted transversely, but if portions be selected where the branches are at fairly regular distances apart and the meshes consequently of pretty uniform width, the number will be found to be about 25 (say 23–27).

Remarks. C. subretiformis is so well distinguished by its "straggling aspect" that it can not be easily confounded with any other form. The meshwork in Spencer's figure is distinctly coarser than that in any of our specimens, but as the latter agrees in its dimensions with those given by Gurley for C. subretiformis, the difference can be but small.

One of our specimens, a young colony, retains the base in the form of a thin, short (3 mm) stem and of an adhesion disk, a little more than 2 mm wide. The form of the rhabdosome was very broadly infundibuliform.

The thecae have not been seen.

Spencer has erected the genus Calyptograptus for several species of the Niagaran of Hamilton, Ontario, which are principally distinguished from the similar genera, notably Dictyonema and Callograptus, by the absence of transverse dissepiments. In the first diagnosis it is stated that "in appearance and texture this genus resembles Dictyonema, but the branches are [apparently] all independent, not being connected by transverse dissepiments as in that genus and are only united in one mass at the root," [although some of the branches touching each other have occasionally all the appearance of connecting filaments]. This statement has later (1884) been qualified by the same author by the additions here placed in brackets, both of which tend to admit the occasional presence of dissepiments. The absence of the dissepiments and the independence of the

branches down to the root, which may be considered as additional diagnostic characters of the genus, find their strictest expression in C. cyathiformis, the form which is cited as the genotype by Miller [N. Am. Geol. & Pal. 1889, p.175].

As both Spencer's drawings and our material show, these characters are not retained in his second species, C. subretiformis. The latter clearly possesses dissepiments which however are so oblique, that they appear as bifurcations [*see* Spencer's figure, here copied]. Dictyonema polymorphum Gurley indicates the transition from a typical Dictyonema with rectangular meshes to this irregularly meshed form. The clearly closer relationship of the present species to Dictyonema polymorphum than to C. cyathiformis has induced us to place it under the former genus and to restrict Calyptograptus to forms which retain the diagnostic characters of the genotype.

Dictyonema areyi Gurley ms

Plate 4, figure 2

Dr Gurley describes this form as follows:

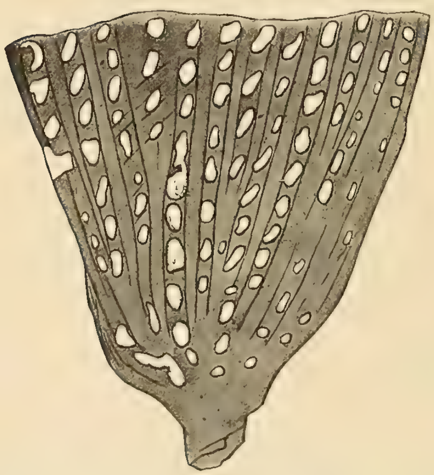


Fig. 73 Dictyonema areyi Gurley ms. Enlargement (x 5) of basal portion of type specimen

Polypary arising from a bulbous base, cyathiform, hardly at all radiate, the sides subparallel above. Branches 0.6 mm wide, and 30 in a width of 25 mm; dissepiments *very* heavy (some reaching 0.6 mm), concave-sided, 25 in 25 mm. But they may be (often are) much narrower either from wearing or from the shale not splitting accurately in their plane. Meshes rounded-oblong, or elliptic. Thecae invisible.

Horizon and locality. Niagara shale, Rochester, N. Y. Four specimens (including the types) in collection of Prof. A. L. Arey, Rochester, N. Y., to whom the species is dedicated.

This species is about the most distinct of the genus, hardly resembling any other. The specimens consist only of flattened blacker films on the black shale. But the great thickness of the dissepiments, their biconcave-sided character and the consequent rounded oblong, or oval meshes, easily characterize the species.

We have added a natural size drawing and a camera enlargement of one of Gurley's three types (cotypes).

Dictyonema crassum Girty

Plate 5, figures 3, 4

Dictyonema crassum Girty. N. Y. State Geol. 14th An. Rep't, 1894. 1895. p.289; pl. 4, fig. 1, 2

The original description of this species is:

Shape of entire frond not known. The largest fragment measures 7.5 by 7.5 cm. The branches are marked by coarse longitudinal striae, or wrinkles, which are not continuous. The dissepiments are nearly equal in size and parallel in direction, forming with the branches a rather uniform reticulation. Both branches and dissepiments are enlarged at their point of union, giving the fenestrules a more or less rounded form. Thickness of branches, .5 to 1 mm. Dissepiments of about the same size. The specimens examined are casts.

The zoarium in Dictyonema crassum is coarser than in D. retiforme Hall, of the Niagara group, the dissepiments heavier, and the fenestrules more rounded.

The quality of the material would hardly warrant the description of a new species, were it not that this is the first appearance of the genus noted in Lower Helderberg strata.

Horizon. Shaly limestone.

Locality. Clarksville, Albany co., N. Y.

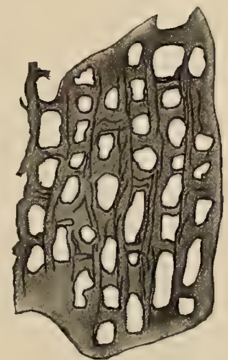


Fig. 74 Dictyonema crassum Girty. Enlargement (x 5) of portion of type specimen

Since this careful and correct description is accompanied only by camera enlargements of portions giving the outlines of the fenestrules and therefore furnishing a very inadequate picture for purposes of comparison, I have inserted here an enlargement and a natural size drawing of a portion of the type specimen which was kindly loaned to me by Professor Schuchert.

Better preserved than the two type specimens which were collected by the late Professor Beecher in the Helderbergs near Albany and are now in the Yale University Museum, are numerous specimens now in the New York State Museum. One of these, still further to be noted below is from the New Scotland limestone (Shaly limestone) near Catskill, N. Y. and the remainder are from the same formation in the Jonesburg quarry at

Becraft mountain where they were discovered last year by Mr Wardell. They are there associated with a large Desmograptus and quite common, though hitherto not recorded.

The specimen from Catskill [*see* pl. 5, fig. 3] is of especial interest since it shows that the frond had a rather slender infundibuliform shape. It retains both lateral margins for some distance and also both the upper and lower sides, the two being separated by a shaly layer about 1 mm thick and the lower side exposed at the proximal end of the fragment.

The thecae could not be seen in any of the specimens. Judging from the length of some fragments the form must have reached quite respectable proportions. One fragment which is clearly but a small portion of the distal part, measures 105 mm in length. Most fragments have as common characteristics the straight, often somewhat rigid direction of the branches and the great thickness and terminal spreading of the dissepiments which give to the fenestrules a circular shape. It is, however, obvious that this species is subject to considerable variation, for on one hand one meets portions of the frond where the branches become almost abruptly undulating and a Desmograptuslike structure is approached, as in the distal part of plate 5, figure 3; and on the other hand, in large portions both branches and dissepiments become more delicate and the meshes long rectangular. When separated, these so different looking parts of fronds would certainly be taken as belonging to different species, but being parts of continuous fronds, they illustrate the uncertainty of species determination by the character of the meshes in Dictyonema.

Gurley and Girty published their Devonic Dictyonemas at nearly the same time apparently without knowing of each other's species, for Gurley has not mentioned D. crassum in his list of 1896, nor in his manuscript, and Girty compares his species only with D. retiforme of the Niagaran. Since the Lower Helderberg formation has now, however, been recognized to be a part of the Devonic, the possibility of the specific identity of this form with the longer known D. hamiltoniae arises, and indeed a comparison of the types of the two forms brings out a strange identity in

the general dimensions (width of branches, distance of branches, etc.) and the above mentioned more delicate portions of D. crassum would seem to differ not at all from D. hamiltoniae. In general the branches of D. crassum are however thicker and since they are in both equally distant from each other (25 in 25 mm), the open intervals in D. crassum are considerably smaller. Also the dissepiments are as a rule, placed considerably nearer together.

Gurley has described in his manuscript three species of Dictyonemas from the Onondaga limestone of Leroy, N. Y. [*see* D. megadictyon, D. leroyense and D. perradiatum]. From all of these D. crassum is readily distinguished. It is less coarse than the first two and coarser than the last one.

Dictyonema leroyense Gurley ms

Plate 3, figure 3

Gurley's description is:

Polypary arising from and sessile upon a discoid base which consists of a carbonaceous film in which structure is evident but which, from the state of preservation, cannot be more closely described than as consisting of a number of minute elliptical pores about 0.3 mm long, 0.2 mm wide, and about 0.2 mm apart (say 0.4, center to center). In addition the surface seems to present a tendency to an apparently subregular mammillation, but this is less certain.

Polypary, in circularly compressed specimens, radiating somewhat rapidly, in those compressed from the side not expanding so rapidly; 10 mm long, and 15 mm wide. Branches rather straight, subparallel, 17–20 in 25 mm, about 0.6 mm wide, judging from the few places where they are satisfactorily exposed. Dissepiments of medium thickness, about 13–15 in 25 mm, usually straight and transverse. Meshes typically subquadrangular, occasionally less regular. Thecae invisible.

Horizon and locality. Two specimens in the National Museum from the Corniferous limestone (Upper Helderberg formation), Leroy, N. Y. Collector, Charles Schuchert.

This species most nearly approaches D. megadictyon from the same beds, but the branches are straighter, and both they and the dissepiments are more numerous and more slender than in that species. The structure of the base is — in so far as it can be made out — in exact accord with that found in D. polymorphum of the Niagara. And this agreement may perhaps furnish a valid basis for a generic distinction

between these upper Paleozoic Dictyonemata and those of the Upper Cambrian and Lower Ordovician.

Dictyonema megadictyon Gurley ms

Plate 5, figure 5

Gurley's description is:

Polypary in the type specimen very stout, moderately radiate. Branches subparallel, very thick, apparently not uniformly so, thickenings seeming to take place especially just below the points of bifurcation; about 0.8–1.0 mm (0.6–1.2 mm the extreme limits; the great apparent range probably due to imperfect exposure or flattening); only 12–14 in 25 mm. Dissepiments very thick. One measured more than 1 mm wide, and being slightly oblique gave the impression of branch fusion, as in *Desmograptus*. Dissepiments often curved. Meshes usually quadrangular but sometimes less regular being subrhomboidal or trapezoidal.

Horizon and locality. Three specimens in National Museum from the Corniferous limestone (Upper Helderberg formation), Leroy, N. Y. Collector, Charles Schuchert.

The great coarseness of the meshwork and branches is a distinctive feature which separates it at a glance from most species of the genus.

Dictyonema perradiatum Gurley ms

cf. D. fenestratum Hall

Plate 4, figure 3

Gurley's description of this form is:

Polypary palmately radiating, the lateral branches retrocurved. Branches 30–32 in 25 mm of width, 0.4 mm thick, except a very few of the proximal ones which reach 0.5 mm or occasionally even 0.6 mm. Corresponding to the amount of radiation the branches in places arise not by dichotomy but branch off more or less laterally as from a main stem. Meshes usually about 1.–1.25 mm long. At the origin of the dissepiments the branches sometimes bend slightly inward (toward the dissepiments), thus narrowing the mesh and giving it a slightly elongated hexagonal form, and the branches a slightly zigzag wavy appearance. Thecae about 60–65 in 25 mm.

Horizon and locality. One specimen in the National Museum from the Upper Helderberg formation (Corniferous limestone), Leroy, N. Y. Collector, Charles Schuchert.

This is a well marked species. Perhaps it resembles D. crassibasale (Gurley manuscript) as closely as any other species, but it lacks the main distinctive characters of that species, not having the branches so undulate or so heavy, and having them more numerous in 25 mm of width. Besides it is a more spreading form.

Dr Whiteaves has sent me for inspection two specimens which are clearly conspecific with the Leroy type. Both come from the Onondaga (Corniferous) limestone of Ontario, Canada, one from Walpole, the other from Oneida.

Dictyonema fenestratum Hall

Dictyonema fenestrata Hall. Foster & Whitney's Geology Lake Superior Land Distr. pt 2. 1851. p.223–24; pl. 35. fig. 1a, b

Dictyonema fenestrata Hall. Can. Org. Rem. Dec. 2. 1865. p.58

Dictyonema fenestrata Hall. N. Y. State Cab. Nat. Hist. 20th Rep't. 1868. p.224

Dictyonema fenestratum Pocta. Syst. Sil. Bohême. 1894. v. 8, t. 1, p.192

Dictyonema fenestratum Gurley. Jour. Geol. 1896. 4:308

Dictyonema fenestratum Frech. Leth. Pal. 1897. 1:576

Fig. 75 Dictyonema fenestratum Hall. Copies of original figures

This Devonic species which is based upon a fragment from the "argillaceous limestone of Mackinac,"[1] though repeatedly cited as one of the Devonic Dictyonemas, has not been figured or described again and I have been unable to locate the type. Hall compares it with D. gracile of the Niagara group. Of the Devonic species described in this volume, it resembles only D. perradiatum in its habitus and if Hall's figure is correct, there can be but little or no difference at all between the two species, both showing the same dimensions.

Dictyonema hamiltoniae Hall (Gurley emend.)

Plate 4, figure 4

Dictyonema hamiltoniae (*nomen nudum*) Hall. Can. Org. Rem. Dec. 2. 1865. p.53

Dictyonema actinotum Gurley. Jour. Geol. 1896. 4:82

Dictyonema hamiltoniae? Grabau. Buff. Soc. Nat. Sci. Bul. 1899. 4:120, fig. 1

[1] Frech [*loc. cit.*] has erroneously cited it as a form from the State of New York.

The first (Gurley's) description of this species is:

Specimens seem very incomplete. Branches radiating rapidly, bifurcating mostly near the base (in correspondence with their rapid radiation) rather conspicuously longitudinal striate, 0.5–0.6 mm wide, 25–30 in 25 mm. Dissepiments rather stout, wiry, apt to be curved, transverse or slightly oblique. Meshes subquadrangular or with rounded angles. Thecae present but indistinct. Length of mesh uncertain, perhaps 2–2.5 mm.

Horizon and locality. Devonian (Hamilton formation), Kashong creek, Cayuga county, N. Y. Several specimens, badly preserved but apparently of this species, occur in the Hamilton at Moscow, N. Y.

All specimens and the type in American Museum Natural History, New York city.

The specimen from Kashong creek which Gurley considers as the type of the species, has never been in the Hall collection as Professor Whitfield informs me, but was sent to Professor Whitfield by B. H. Wright of Penn Yan for identification. On the other hand, one of the two specimens from Moscow, N. Y., here cited as apparently belonging to this species, bears the locality ticket of the old Hall collection and is therefore more probably one of Hall's types. Since all three specimens are clearly conspecific, the matter is of little importance; and since the species has not been figured or described before, no confusion can be created by retaining Hall's name for it, while on the other hand, the fact that Hall's name has gotten into the literature for this, the more common of the two Hamilton species, makes the adoption of a new name undesirable. Thus e. g. the specimens from the Hamilton shale of the lake shore of Erie county, N. Y. referred by Professor Grabau provisionally to this species, belong according to his figures undoubtedly hither.

Fig. 76 Dictyonema hamiltoniae Hall. Enlargement (x 5) of portion of one of the supposed type specimens from Moscow, N. Y. in the Am. Mus. Nat. Hist. Shows character of thecae and dissepiments

By way of completion of the above given description, we may add that this form receives its characteristic habitus mainly from the rigid straightness and close arrangement of its thin branches, that, however, the proximal portion is distinctly desmograptoid in one of the specimens. The composi-

tion of the branches of many (supposed zoothecal and gonothecal) tubes gives them the appearance of twisted ropes, a feature that is especially noticeable in the Kashong creek specimens. One of the specimens from Moscow is so far abraded that only the denticles of the thecae are preserved as black pits. These number 20–22 in the space of 10 mm. A like close arrangement of the thecae is indicated by one of the specimens from Moscow where they are seen in profile on small portions of the twisted branches [*see* fig. 76]. The thecae in that specimen appear to have had the shape of birds' nests and been flanked by smaller apertures, while the dissepiments are preserved as broad ribbons.

Dictyonema blairi Gurley

Plate 3, figure 2

Dictyonema blairi Gurley. 1896. Jour. Geol. 4: 82–83

Proximal end of polypary unknown. Branches radiating slowly, subparallel; usually scarcely but nearly 0.4 mm thick, 0.5 mm occasionally *ad max.*, and arranged transversely, about 20–25 in 25 mm. Interspaces generally about one and one half times as wide as branches or slightly more. Dissepiments rather slender, about 0.25 mm thick *ad max.*; sometimes straight, usually more or less oblique. Meshes correspondingly variable in shape, from quadrangular to triangular. The shortest are about 1.25 mm long, and the greatest length in unbroken meshes (i. e. where all the dissepiments are entire) is probably near 3 mm. Texture black carbonaceous. Branches rather obscurely striate, dividing at an acute, rather sharp angle.

Resembles somewhat D. gracile Hall, but the branches are a little more slender and the interspaces a little wider, and especially the number of branches transversely in this species is less (20–25 as against 25–30 in D. gracile). I am indebted to Mr Charles Schuchert for having drawn my attention to this species.

Horizon and locality. Lower Carboniferous (Choteau limestone), Sedalia, Mo. Collected by and dedicated to Mr R. A. Blair, of Sedalia.

A manuscript note by Gurley reads:

To this, in the light of more material, I can now add partly by way of correction, that very rarely a single branch may be seen 0.6 mm wide, usually just below a bifurcation; also that occasional meshes as short as 1 mm, and very rarely one as short as 0.5 mm, may be found.

In all 39 specimens, many being fragments.

On the occasion of discussing the range of the graptolites [Mem. 7,

p.488] the writer has, misled by information from second hand, remarked in a footnote that D. blairi is a very doubtful graptolite and according to last accounts but the remains of a plant. In doing so an error has been perpetuated, for specimens which Mr Bassler has, upon my request, kindly forwarded to me leave no doubt of this being a true Dictyonema.

Since no drawings of this most interesting form have been published thus far, I have added a tracing in natural size and camera enlargements. One fragment is the basal part of a rhabdosome and indicates by the

77

78

Fig. 77, 78 Dictyonema blairi Gurley. Fig. 77 Enlargement (x 5) of portion of type specimen. Fig. 78 Fragment showing natural section. x 6. Originals in National Museum

arrangement of the branches an original infundibuliform shape of the specimen. The sicula is not preserved and the thecae are not well shown in any of the specimens.

ODONTOCAULIS Lapworth

Odontocaulis Lapworth. Geol. Soc. Lond. Quar. Jour. 1881. 37:176

Original diagnosis:

Gen. char. Polypary cyathiforme, composed of numerous independent and frequently bifurcating polypiferous branches, originating from the distal extremity of a short stem, which is likewise polypiferous, and is terminated proximally in an irregular corneous expansion. Hydrothecae of the type of those of *Dictyonema*, biserial, subalternate.

The chief peculiarity of this genus is afforded by the character of the stem, which is identical in every respect with the main branches, and, like them, is denticulate or polypiferous throughout the whole of its extent. It commences proximally in a flattened expansion, with irregular or frayed out edges, possibly the remains of a disk or bulb of attachment.

The mode of branching is rigidly dichotomous, the first two branches being formed by the subdivision of the main stem itself. Each arm branches and rebranches again and again in the same manner, at frequent and close intervals, composing an elegant cyathiform or fanlike polypary, very symmetrical in form. The branches retain their original width to their final division, which gives rise to two minute branches less than one tenth of an inch in length.

The hydrothecae are more prominent than those upon Dictyonema. The distal extremity of each appears to have been free and slightly introverted, as in the majority of the bilateral family of the Dicranograptidae.

Odontocaulis is separated from *Dictyonema* by the absence of the transverse dissepiments, and by the polypiferous character of the stem. From *Callograptus*, which it much resembles, the same features effectually distinguish it. In *Dendrograptus* the stem is stout and devoid of polyps, while the branches are irregularly disposed; in the present genus the stem is no thicker than the branches, is polypiferous, and the branches are regularly and symmetrically subdivided. It has probably its nearest ally in *Rhizograptus* [Spencer, Canadian Naturalist, 1879, p.460]; but in that genus the stem appears to be barren, and the branches are possibly united at intervals.

Dr Gurley remarks on Odontocaulis in his manuscript:

This genus was thus established by Lapworth for forms which virtually combined two characters: (1) Absence of dissepiments, and (2) a polypiferous stem. Its only distinctions from *Dictyonema* and *Callograptus* lay in these two features. But in O. occidentalis we find dissepiments *along with* the polypiferous stem. Whence there is now no generic distinction whatever between these two *Odontocaulis* species and the *Callograptus* species at the same horizon, except the single one of the thecae on the stem. But it is not at all improbable that this is merely a question of better preservation, well preserved stems being thecate. At least, of the two specimens of *O. occidentalis*, both showing the stem, one shows thecae perfectly, the other only very obscurely.

Having said this, however, a contingency may properly be noted. May it be possible that *all* the Callograpti at this horizon have thecate stems (in other words, all be referable to Odontocaulis)? There is, I think, some ground for such a surmise. As Holm has said for *Dictyonema*, so now for *Callograptus*, the very great geologic range of the genus is a

reason for suspecting the validity of the generic reference of the species. May it not then be possible that, compelled as we are for the most part to deal with and to base our species upon fragments of the meshwork, we are confounding two series; say for illustration[1] a series lower Ordovician (Calciferous) in distribution, and a series Upper Silurian (Niagara) in distribution, both series agreeing in type of meshwork (probably a character of subordinate biologic value), but differing in characters of the base? At present there is nothing to negative such a view. Until we know the proximal portion of the type species (C. salteri) this reasoning must of course remain purely a possibility. But in a review like the present, a clear outlining of future possibilities may be justifiable. Certainly only under some such condition, it seems to me, would *Odontocaulis* stand much chance of ultimate retention. Its provisional retention, I think advisable, pending a fuller knowledge of the condition of the base in the remaining Niagara *Callograptus* species. At present its most distinctive characters seem to be: *Polypary arising from a single stem which is expanded proximally into a "disk," and is thecaphorous along one side; distal branches more or less connected by dissepiments.*

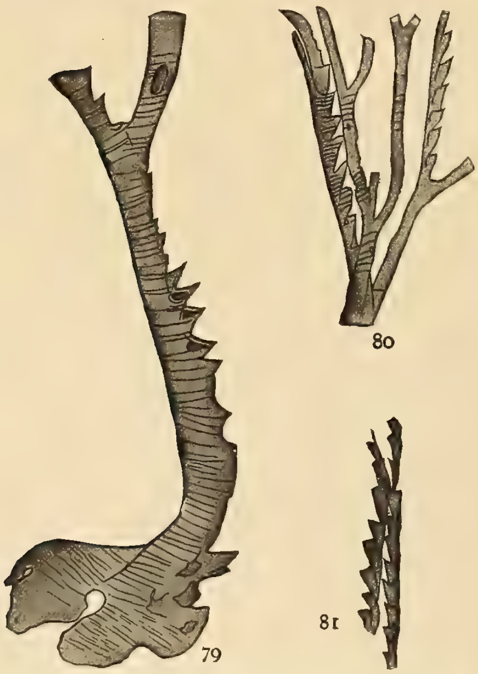


Fig. 79–81 Odontocaulis hepaticus sp. nov. Fig. 79 Enlargement (x 6) of basal portion of type speci men. The transverse lines represent cracks in the thick periderm. Fig 80 (x 6) 81 (x 5) Enlargement of portions showing the form of the thecae

Odontocaulis hepaticus sp. nov.

Plate 1, figures 6, 7

Description. Rhabdosome of small or moderate size (65+ mm), consisting of a deeply lobate basal disk (5 mm), short but stout theciferous stem and the probably infundibuliform frond. Branches frequently bifurcating, the resulting branches little diverging, closely arranged, of rigid appearance, nearly straight, with an average width of .3 mm–.5 mm, not connected by dissepiments. Thecae perspicuous with acute denticles, inclined 30° to axis of branch, numbering 14–15 in 10 mm; ventral margin straight or

[1] For illustration only, and as a pure surmise of the possibilities of the case.

slightly convex, apertural margin gently concave, and normal to axis of theca. Without apertural appendages.

Position and locality. In the Normanskill shale at Glenmont, Albany co., N. Y. On some slabs associated with Dicellogr. gurleyi, on others with Dicranogr. nicholsoni var. diapason.

Remarks. This species is based mainly on two specimens (cotypes), one of which exhibits splendidly the basal parts, but has the frond much broken and stripped, while the other lacks the base, but appears to retain the whole frond. The thecae and dimensions of the branches are the same in both.

While the frond occupies in one specimen only a section of a circle and has the appearance of a flabellate form, it is more probable that originally it was infundibuliform, for the branches are densely crowded along the two radial sides and lie in the middle part distinctly in two layers which have somewhat different directions.

In its general habitus the form reminds one most of Callograptus salteri from the Beekmantown beds. It has received its name from the peculiarly lobate form of the disk which strongly recalls the liverwort.

PTIOGRAPTUS gen. nov.

Etym. *ption*, fan ; *grapho*, I write

This generic term is proposed for a species which in its subparallel branches connected by transverse dissepiments resembles a Dictyonema but differs mainly in having a flabellate rhabdosome instead of the cyathiform or infundibuliform one of Dictyonema *s. str.* The genotype — and thus far single species — P. percorrugatus, is distinguished besides from most species of Dictyonema in the marked alternating emptying of the thecae on opposite sides of the branches and the resulting alternate arrangement of the apertural processes. Similar apertural processes have been described by Wiman of D. peltatum and D. cavernosum and by the writer of D. furciferum, but in these they are only found on one side of the branches and they do not unite with those of the opposite branches forming new processes which grow parallel to the

branches [*see* fig. 82, 83]. These latter features are hence probably additional diagnostic characters of the genus.

As diagnostic characters of the genus as far as they can be derived from one species, we may then consider: the flabellate form, the presence of processes on both sides of the branches and the union of these processes.

The arrangement of the apertural spines on both sides of the branches produces an aspect that is very suggestive of Acanthograptus and may easily lead to the conclusion that Ptiograptus is an Acanthograptus whose rhabdosome has become fixed by a close system of transverse dissepiments and that this approach in aspect to Dictyonema is due to convergence. In that case, however, the "spines" would have to be composed of bundles of emptying thecae. This point could be cleared only by an investigation of etched material — which with the single split rhabdosome in hand is impossible -- but it can be said that the spines have not the appearance of composite bodies and that their uniting into new processes is also little indicative of such composition.

But granted that its relations were with Acanthograptus; in that case it would be still generically differentiated by the uniting of the processes.

Genotype: Ptiograptus percorrugatus sp. nov.

Ptiograptus percorrugatus sp. nov.

Plate 5, figure 6

Description. Rhabdosome of medium size (67 mm high, 78 mm wide) flabellate, branches quite uniformly .4 mm wide (.6 mm near base), very closely arranged (6–7 in 10 mm, intervals .8 mm–1 mm), subparallel, irregularly curved, of extremely knotty and wrinkled appearance which is due partly to the arrangement of the thecae which empty alternately on opposite sides of the branches and give the latter thereby a zigzag direction; and partly to the presence of long apertural processes on the thecae. The latter are bent obliquely forward or upward, apparently furcate at their extremities, and overlap or unite frequently with those of the opposite side, the resulting process growing forward midway between and subparallel to the branches [*see* text fig. 82]. These processes together with the very thin, forward

curving dissepiments give the whole rhabdosome the appearance of a leaf with extremely close venation. The thecae open alternately on opposite sides of the branch, and number 11–13 in 10 mm.

Position and locality. We have seen but one specimen which is labeled as coming from the waterlime at Louisville, Ky. (Middle Devonic).

Remarks. There is no North American graptolite known to me to which this very curious form bears any resemblance. Its flabellate form,


82


83

Fig. 82, 83 Ptiograptus percorrugatus sp. nov. Fig. 82 Enlargement (x 5) of middle portion of rhabdosome. Fig. 83 Enlargement (x 5) of marginal portion

closely zigzagged branches and uniting furcate appendages give it a striking aspect and an isolated position which we have given recognition by making it a genotype.

DESMOGRAPTUS Hopkinson

See N. Y. State Mus. Mem. 7, p. 609

Desmograptus tenuiramosus sp. nov.

Plate 1, figure 2

Description. Rhabdosome small, flabellate, of extremely delicate appearance. Branches very thin (.14 mm wide), frequently bifurcating, the resulting branches diverging at an angle of 40°, strongly undulating and frequently reuniting, in some places connected by dissepiments; the meshes elongate elliptic, about 3 mm long. Thecae long, slender, dis-

tinctly projecting, inclined at 15°, and furnished with short apertural mucros. Their apertural margins slightly concave. They number about 14 in the space of 10 mm. Sicula and stem not observed.

Position and locality. A single specimen observed in the Normanskill shale at Glenmont near Albany, on one of the slabs that are covered with a dense mass of Dicellograptus gurleyi.

Remarks. In its habit this species bears closer resemblance to Callograptus elegans Hall, than to any other species we know; and inasmuch as that species is the genotype of Callograptus, a reference of our species to Callograptus will suggest itself at first sight. We have preferred to place it with Desmograptus for two reasons; first, the strong development of the undulations and reunions of the branches and second, the prominence of the thecae. The first character is just indicated in Callograptus elegans; one could therefore assume that it had been further developed in D. tenuiramosus, especially since in the latter also dissepiments are observed between the branches when these fail to approach sufficiently. In this regard our species would hence seem to hold a position between the genera Callograptus and Desmograptus, similarly as other forms seem to connect Callograptus and Dictyonema. The thecae however, exhibit a form hitherto not observed in species of Callograptus; they remind one of those of Dendrograptus *s. str.* and Dictyonema. But also in regard to the thecal form, there seem to exist within the confines of Desmograptus and Callograptus divergencies such as were found in Dendrograptus (here separated into Dendrograptus *s. str.* and Mastigograptus by this criterion).

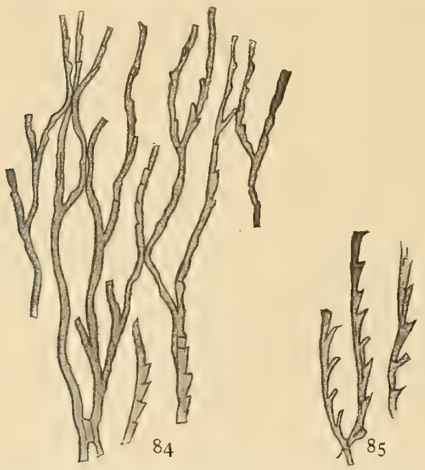


Fig. 84, 85 Desmograptus tenuiramosus sp. nov. Fig. 84 Enlargement of portion of type specimen showing form of branches. Fig. 85 Enlargement of other portion showing form of thecae. x 5

Desmograptus pergracilis (Hall & Whitfield)

Dictyonema pergracile Hall & Whitfield. N. Y. State Mus. Nat. Hist. 24th An. Rep't. 1872. p.181

Dictyonema pergracile Hall & Whitfield. N. Y. State Mus. 27th An. Rep't. 1875. pl. 9, fig. 38

Dictyonema pergracile Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 577

Dictyonema pergracile Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 14, 17

Dictyonema pergracile Počta. Syst. Sil. Bohême. 1894. v. 8, t. 1, p.193

Dictyonema pergracile Gurley. Jour. Geol. 1896. 4: 308

Regarding this species Dr Gurley remarks:

The Niagara collections from Hamilton yield no material which can with certainty be referred to this species. Indeed, in the absence of a figure, it would be hard to feel much certainty as to any identification even of the material from the type locality. It is not impossible, however, that the form I have named Dictyonema gracile filiramus (in manuscript) may prove to be pergracile, as it agrees with it as far as the meager diagnosis goes.

The figure of this species, together with those of the other species from Louisville was not published until the 27th Report of the New York State Museum, a fact which evidently has been overlooked by Gurley and the other authors, who cite the form. Počta would surely have referred this form to Desmograptus which genus is well represented in his fauna and recognized by him, had he seen the figure and Gurley would not have thought of the possibility of its identity with his Dictyonema gracile filiramus.

Professor Whitfield informs me that the type of this species was in the cabinet of Dr Knapp. It has probably been sold lately with the Hall collection to Chicago University and is at present inaccessible.

Desmograptus becraftensis sp. nov.

Plate 5, figure 1

Description. Rhabdosome large; an incomplete specimen measuring 30 cm in diameter; broadly infundibuliform and rapidly expanding. Branches throughout frequently bifurcating and regularly undulating, forming by refusion with the neighboring branches narrow, elongate

lozenge-shaped meshes. There are about six to eight meshes in 10 mm transversely and two to three in the same distance longitudinally in the compressed state. The thecae and the base have not been seen.

Formation and locality. Discovered by Mr H. C. Wardell in a quarry of the Becraft Cement Co. in the New Scotland beds at Jonesburg on Becraft mountain, near Hudson, N. Y. where in association with Dictyonema crassum it is not uncommon.

Remarks. As in the case of Dictyonema crassum, the possibility of the identity of this species with the longer known Hamilton form D. cadens Hall (Desmograptus devonicus Gurley) suggests itself, and to continue the parallel, here also the similarity is great enough to indicate close relationship but not sufficient to warrant identification, in the face of the considerable time interval from the base of the Paleodevonic to the top of the Mesodevonic. The meshes are in this form narrower or relatively longer, so that measured transversely there are counted more in the same distance, while in the longitudinal direction they are about of equal size. The meshwork looks, therefore, when compared with that of D. cadens, as if it had been slightly pulled in the longitudinal direction. The branches are also somewhat thinner than in the latter form.

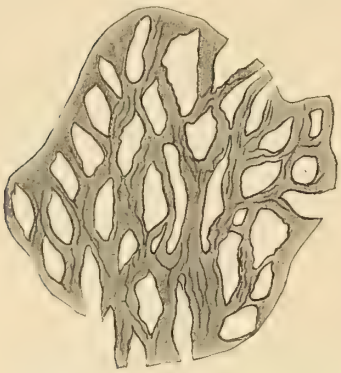


Fig. 86 Desmograptus becraftensis sp. nov. Enlargement (x 3½) of portion of type specimen

Desmograptus cadens (Hall)

Plate 4, figure 1

Dictyonema cadens (nomen nudum) Hall. Can. Org. Rem. Dec. 2. 1865. p.58
Desmograptus devonicus Gurley. Jour. Geol. 1896. 4:84

Gurley's description is:

Polypary very irregular in its mode of growth; scarcely a true dissepiment present. Branches dividing and re-fusing irregularly, leaving round elliptic or round quadrangular (the prevailing type) meshes. The irregularity renders an accurate count of the branches difficult, but there seem to be about 12–15 in 25 mm. The thickness varies considerably though most

of the branches measure 1 mm or nearly that. Longitudinally there are about 6 or 7 meshes in 25 mm.

Horizon and locality. Devonian (Hamilton formation), Moscow, N. Y. Specimens including the type in the American Museum of Natural History, New York city.

We may add to Gurley's description that the type specimen while in its major part a typical round meshed Desmograptus shows in its upper part distinct evidence of transition into a Dictyonema *s. str.* and may hence be but a fragment of the basal portion of a larger rhabdosome.

No thecal denticles are visible on the specimen and the component tubes of the branches fail likewise to be observed through the thick smooth perisark of the branches. From Dictyonema hamiltoniae this form is easily distinguished, even if it should be a Dictyonema, by the greater coarseness of its whole structure. Gurley in 1896 proposed a new name for this form on the ground that Hall's name is but a *nomen nudum*, but since Hall's type was known no necessity for proposing a new name existed and the retention of the old name in describing the species was quite proper.

Desmograptus vandelooi sp. nov.[1]

Plate 5, figure 2

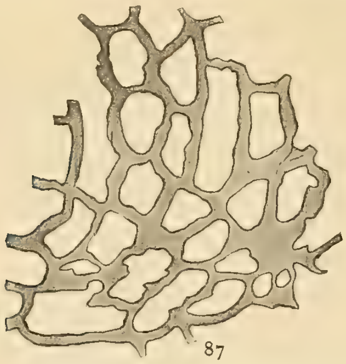
Description. Rhabdosome probably flabelliform, consisting of a very irregular and rather fine meshwork, the branches in some parts subparallel with distinct dissepiments, in others undulating and merely re-fusing at the points of contact. The meshes accordingly elliptic to rounded squarish or rectangular. There are 8 to 11 branches in 10 mm transversely and about 6 to 8 longitudinally. The branches are in the average .6 mm wide and the meshes measure twice as much. The dissepiments where present, are straight and half as wide as the branches.

The thecae, and the stem have not been observed.

Formation and locality. One specimen from the Hamilton beds (near their base) of Hemlock creek, Richmond township, Ontario co., N. Y.

[1] Named in honor of the late Christian Van Deloo, who for more than a score of years was one of Professor Hall's most industrious and successful collectors of fossils and also secured the specimen here described.

Remarks. This form is, in most respects, a smaller edition of its Hamilton congener D. cadens; and could, with some propriety, be considered as a finer meshed variety of the same. Since, however, at present we have no other criteria of specific determination of a Dictyonema and Desmograptus than the dimensions of their meshwork and transitions between the two Hamilton forms are unknown, the ends of taxonomy seem to be served best by sharply separating them.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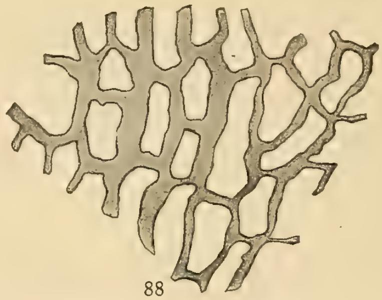
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Fig. 87, 88 Desmograptus vandelooi sp. nov. Enlargements (x 5) of portions of the type specimen showing different aspects of rhabdosome

Like Desmograptus cadens, this species could be as well referred to Dictyonema as to Desmograptus; and the final generic determination of the two has to await the finding of complete rhabdosomes.

CYCLOGRAPTUS Spencer[1]

Spencer's description of this genus is as follows:

In this genus, the frond consists of a circular disk which was probably cup-shaped in its growing form, though flattened in a concave manner in the rock. From the radicle many stipes radiate through the noncelluliferous disk to its margin, and thence in a free manner to some distance beyond. The whole frond resembles a solid wheel, where the radiating spokes extend from the center regularly to beyond the circumference. The branches beyond the disk are celluliferous. The stipes have a central solid axis. The substance is highly corneous, though in some places replaced by pyrites.

Spencer further points to the resemblance of his genus to the "discoid"

[1] Can. Nat. 1882. 10: 165, *nomen nudum;* Acad. Sci. St Louis. Trans. 1884. 4: 563, 565, 592; Mus. State Mo. Bul. 1884. 1: 13, 15, 42.

species of the Quebec group, commenting on the similarity of the graptolites of the Quebec and Niagara periods. It is needless to state more than that there is no such resemblance, the disk-bearing forms of the Quebec group being Dichograptidae. In fact no graptolite comparable to this unique fossil — for the genus contains only one species as yet — has been thus far found on this side of the Atlantic and we must turn to Europe, where in Rodonograptus Počta, Discograptus and Galeograptus Wiman dendroid genera of like habitus have been made known. One or the other of these is likely to be a synonym of Cyclograptus, for they have been erected without knowledge of that genus which is not mentioned in their diagnoses. Of Rodonograptus it is stated that it is not sufficiently well preserved to permit a positive decision as to whether there exists "an independent discoidal plate from which the branches proceed or whether this plate has been produced by the compression of the branches which approach each other," the latter being in Počta's opinion the more probable interpretation, since, "on the best preserved specimens the central disk has no definite contours." The drawings of Rodonograptus would seem to support this view. Discograptus and Galeograptus, both genera of Dendroidea from the Borkholmer Schicht in the Baltic region, have distinct disks. We have copied here a drawing of one of each [*see* text fig. 89, 90], since these are made from specimens etched out of flint and therefore give a better idea of the original form of the organisms than the compressed shale specimens from our Niagaran and Clinton rocks. It is obvious that both if compressed would give a picture resembling that of our Cyclograptus. The thecae are in both, Galeograptus and Discograptus, quite prominent and provided with apertural processes, those of Galeograptus having given the genus its name. Our form contrasts with this in

Fig. 89 Galeograptus wennersteni Wiman. (x 5). Copy from Wiman

Fig. 90 Discograptus schmidti Wiman. (x 4). Copy from Wiman

that the thecae seem to be very indistinct. This, however, is probably only an apparent difference, and due to the fact that the thecae are, as also in Discograptus, all turned inward on the branches, and the latter exhibit only their frontal sides in the compressed condition.

Cyclograptus rotadentatus Spencer

Plate 2, figure 5

Cyclograptus rotadentatus Spencer. Can. Nat. 1882. 10 : 165

Cyclograptus rotadentatus Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 565, 592, 593; pl. 6, fig. 6, 6a

Cyclograptus rotadentatus Spencer. Mus. Univ. State Mo. Bul. 1884. 1 : 15, 42, 43; pl. 6, fig. 6, 6a

Cyclograptus rotadentatus Miller. N. Am. Geol. & Pal. 1889. p.182, fig. 162

Cyclograptus rotadentatus Gurley. Jour. Geol. 1896. 4 : 94, 309

Spencer's description of this form reads:

Frond circular, with numerous stipes radiating from a common center and projecting like a toothed wheel beyond the margin of a noncelluliferous disk. The frond was probably cup-shaped when growing, with the stipes projecting upwards like a row of spines or of tentacles, but in the rock the fossil is flattened and slightly convex. The stipes originate in the center, and are connected about half their length by their continuous noncelluliferous membrane. Each stipe after passing beyond their solid disk divide into two branches about halfway between their extremities and the margin of the disk. The branches or stipes are traversed by a central cylindrical, smooth, solid axis surrounded by their common canal, which is sometimes only represented by a central depression or elevation, but occasionally its form is well preserved. The rarely indicated cell openings are represented by minute oval depressions in the substance. The texture is highly corneous (or replaced by pyrites).

The diameter of the frond is 2 cm, and of the disk 1 cm; the radiating branches extend half a centimeter beyond the disk, and number between 25 and 30, but, as each is divided, the frond is surrounded by about 60 points. The branches (both through the disk and free portion) are rather over half a millimeter broad, but the terminals are scarcely more than half that thickness and end in sharp points.

Formation and locality. This perfect little species was found in the dolomite of the Niagara formation proper, near the base of the series, at the quarry just west of the "Jolly-cut road," at Hamilton, Ontario.

We have but one specimen [pl. 2, fig. 5][1] which is in the New York State Museum and labeled: Clinton group, Clinton, Oneida co. It is from the red, strongly ferruginous shale of the kind that directly overlies the Clinton iron ore, and surpasses in size Spencer's type, obviously his largest specimen, several times, but does not differ in the thickness, number of branches and frequency of bifurcation and is therefore in the absence of more complete collections from either the Lockport or Clinton beds quite properly identified with the species from Hamilton.

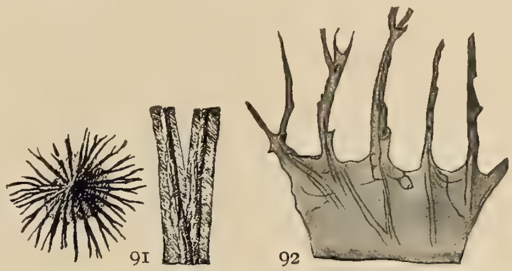

Fig. 91, 92 Cyclograptus rotadentatus Spencer. Fig. 91 Original figures. Fig. 92 Enlargement (x 5) of part of specimen from Clinton shale showing composition of branches of thecae

The dimensions of our specimen are: Diameter of disk 20 mm, that of rhabdosome 25 mm; width of branches not more than .2 mm outside of the disk. There are two concentric zones of bifurcation, the first like the one in Spencer's type, about 5 mm from the center, the second is again as far out. There are counted 55 branches along the periphery. The thecae are only seen in frontal view, as indistinct pores; they seem to number 20 in 10 mm.

INOCAULIS Hall

Hall founded this genus [Pal. N. Y. v. 2] on one species, I. plumulosus, a form of the Rochester shale of New York, giving the following diagnosis:

A plantlike, corneous coral with numerous bifurcating branches; structure fibrous or plumose. The texture of this coral similar to the graptolites, a black, scaly crust or film being all that remains of the substance. From the specimens examined, it appears to have grown in groups, with rounded or flattened stems, which are dichotomous above, and more or less spreading. The structure is too peculiar to be mistaken, or referred to any established genus.

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[1] We have since collected more specimens in the shale overlying the lower ore bed at the same locality.

The author of the genus never felt certain of its true graptolite nature and always cited it among the doubtful genera of graptolites. In the *Graptolites of the Quebec group*, his principal work on this class, he states [p.18]:

Still more obscure, and perhaps remote in its analogies with graptolites, is the genus *Inocaulis*, consisting of flattened scabrous stems, associated with *Dictyonema* in the shale of the Niagara formation, which, from their carbonaceous substance and apparent graptolitic texture, I have referred to the Graptolitidae,

supplementing this note on page 49 as follows:

The genus *Inocaulis* was proposed for some flattened stipes with a scabrous surface, which have the appearance of denticles upon the margins. These stipes grow in close groups or tufts, and are bifurcating or branched in their upper portions. No positive evidence of cellules has been observed. The presence of denticles, together with a corneous and carbonaceous substance, have induced me to place this fossil among the Graptolitidae.

In subsequent years a number of species with irregularly branching rhabdosomes were referred in America to this new genus. They are: I. bellus Hall and Whitfield from the Niagaran of Ohio, I. arbuscula Ulrich from the Cincinnatian of Ohio, I. divaricatus Hall from the Waldron shale of Indiana, I. anastomoticus Ringueberg from the Rochester shale, New York, I. cervicornis, diffusus, phycoides, ramulosus and walkeri Spencer, all from the Niagaran of Hamilton, Ont. and James referred a doubtful form (Licrophycus flabellum) to this genus.

In Europe little notice was taken of Inocaulis, probably because Hall himself expressed doubt of its graptolitic nature. This doubt still finds its expression in the fact that Frech cites it [Leth. pal. p.580] among the doubtful genera. Lindström (1888) compared a species from the Wenlock group of the Island of Gotland with I. bellus and Holm doubts [1890, p.4] whether this form belongs to the true graptolites since it shows no thecae.

Počta [1894, p.197] has described three species (I. aculeata, attrita, and dumetosa) from the Siluric of Bohemia and given a

more elaborate description of the genus, to a part of which we will recur presently.

Finally Wiman [1901, p.191] has described from etched specimens the structure of a species which he refers to Inocaulis (I. musciformis), stating at the same place that he now considers as belonging to the same genus another form which he formerly placed under Ptilograptus (I. suecica).

If these two species are properly placed, the structure of the genus Inocaulis has been demonstrated. The question which hence concerns us next, is whether Wiman's species are to be considered as true representatives of Inocaulis. If we compare his figures with those of I. plumulosus which as the genotype is the last court of appeal, we find at once a striking difference in habit, I. plumulosus having very thick, massive branches which are so densely covered with minute, fingerlike processes [*see* pl. 7, fig. 2] that no interspaces are left, while the Swedish forms have thinner branches which consist of but few tubes and their branchlets are relatively large and far apart. That these differences are not of a fundamental character appears from the fact that in both the branchlets are composed of several thecal tubes, which empty upon them [*see* pl. 7, fig. 1], and from the consideration that the branches of I. plumulosus being so much thicker and composed of so many more thecal tubes, the emptying groups of thecae will naturally be more crowded upon the surface of the massive branches.

The Swedish species are obviously identical in habit with forms described under Acanthograptus in Canada [Spencer 1884] and there is no doubt that Wiman's species as well as Počta's should be properly referred to that genus [*see* p.192]. The latter, however, is undoubtedly so closely related to Inocaulis that the conclusions obtained as to its structure are on the whole transferable to Inocaulis, and we therefore here refer the reader to the description of the structure of Acanthograptus.

If we restrict the genus Inocaulis as here proposed, all the species referred to it by Počta will also have to be removed to Acanthograptus, and

likewise most American species. I. divaricatus Hall is an Inocaulis *s. str.* but I. bella Hall and Whitfield and I. anastomotica Ringueberg lack the projecting bundles of opening thecae and possess other distinguishing features which characterize them as members of a different genus (Palaeodictyota). I. arbuscula Ulrich is a true Dictyonema with dissepiments, and also some of Spencer's species of Inocaulis will have to be placed elsewhere.

As in many other Dendroidea the rhabdosome of Inocaulis was evidently fastened to the bottom of the sea or to other objects. This is already indicated by its association with other Dendroidea as at Hamilton, Ontario, in our Rochester shale and directly demonstrated by the presence of a basal expansion in a specimen of I. plumulosus.

Inocaulis plumulosus Hall

Plate 2, figure 4; plate 7, figures 1, 2

"——?" Hall. Geol. N. Y. 4th Dist. 1843. p.116, fig. 1

Inocaulis plumulosa Hall. Pal. N. Y. 1852. 2: 176; pl. 40G, fig. 2a, 2b

Inocaulis plumulosa Hall. Can. Org. Rem. Dec. 2, 1865. p.18, fig. 26

Inocaulis plumulosa Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1867, p.185, fig. 28

Inocaulis plumulosa Hall. Id. rev. ed. 1870. p.193, fig. 183

Inocaulis plumulosa Spencer. Can. Nat. 1878. 8: 458

Inocaulis plumulosa Spencer. Can. Nat. 1882. 10: 166

Inocaulis plumulosus Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 584. 585; pl. 5, fig. 1

Inocaulis plumulosus Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 14, 34, 35; pl. 5, fig. 1

Inocaulis plumulosus Miller. N. Am. Geol. & Pal. 1889. p.193, 194, fig. 183

Inocaulis plumulosa Počta. Syst. Sil. Bohême. 1894. v. 8, t. 1, p.197

Inocaulis plumulosus Gurley. Jour. Geol. 1896. 4: 99, 309

Hall has given the following diagnosis of this species:

Stems flattened, dichotomous; structure fibrous or plumulose, apparently composed of imbricating elongated scales or fibers which spread equally on all sides.

This coral is not abundant, though small fragments are frequently seen in the slab. It is very often replaced by iron pyrites, and where the surface

is exposed to weathering, the fossil soon disappears, so that it is only on freshly fractured surfaces that the structure is preserved.

It is cited as occurring in the " Niagara shale at Lockport, Rochester and other places."

Spencer has recorded the form from the Niagaran limestone at Hamilton, Ontario.

Gurley, in his manuscript, adds to the descriptions of Hall and Spencer the following note :

Two specimens from the Niagara formation, at Hamilton, Ontario, are figured [*see* fig. 134, 135], showing the blunt toothlike bodies and the apparently dentate margin. While the appearance much resembles thecae, it is impossible to make a positive statement on the material available.

From a fairly large series of good specimens we derive the following data on this important species :

The rhabdosome is arborescent in form ; the branches divide dichotomously at irregular intervals, forming initial angles of 50°–60° but becoming later subparallel ; of large dimensions (maximal length of largest fragment observed 14 cm, width of another 17 cm), the stem near base 5 mm thick, the branches quite uniformly 3 mm. The branches diminish hardly toward the distal extremities which are bluntly rounded. The stem is apparently smooth, the branches are thickly set with short tubular processes which project about 1 mm from the body of the branch, are of uniform width, directed upward and distally slightly bent backward and number, counted along the margin, about 14 in 10 mm. On specimens where the body of the branch has weathered away, exposing the apertures of the reverse side, they are seen to be distributed about equally over the whole branch, being approximately arranged in quincunx and numbering about five in the width of the stem. At the extremities of the branches they form dense tufts.

Remarks. The general habitus of I. plumulosa can be best described by a comparison with a Lepidodendron or a Lycopodium ; it not only resembles these plants in the mode of its branching and the uniformly wide, blunt ending branches but also in their scaly appearance.

Hall's original and later improved figures give a good conception of the general appearance of the form. A more complete specimen from the

Lockport limestone at Hamilton is here reproduced in text figure 93 by a pen drawing made under Gurley's supervision. In plate 2, figure 4 a portion of the same specimen which is partly weathered has been refigured to show

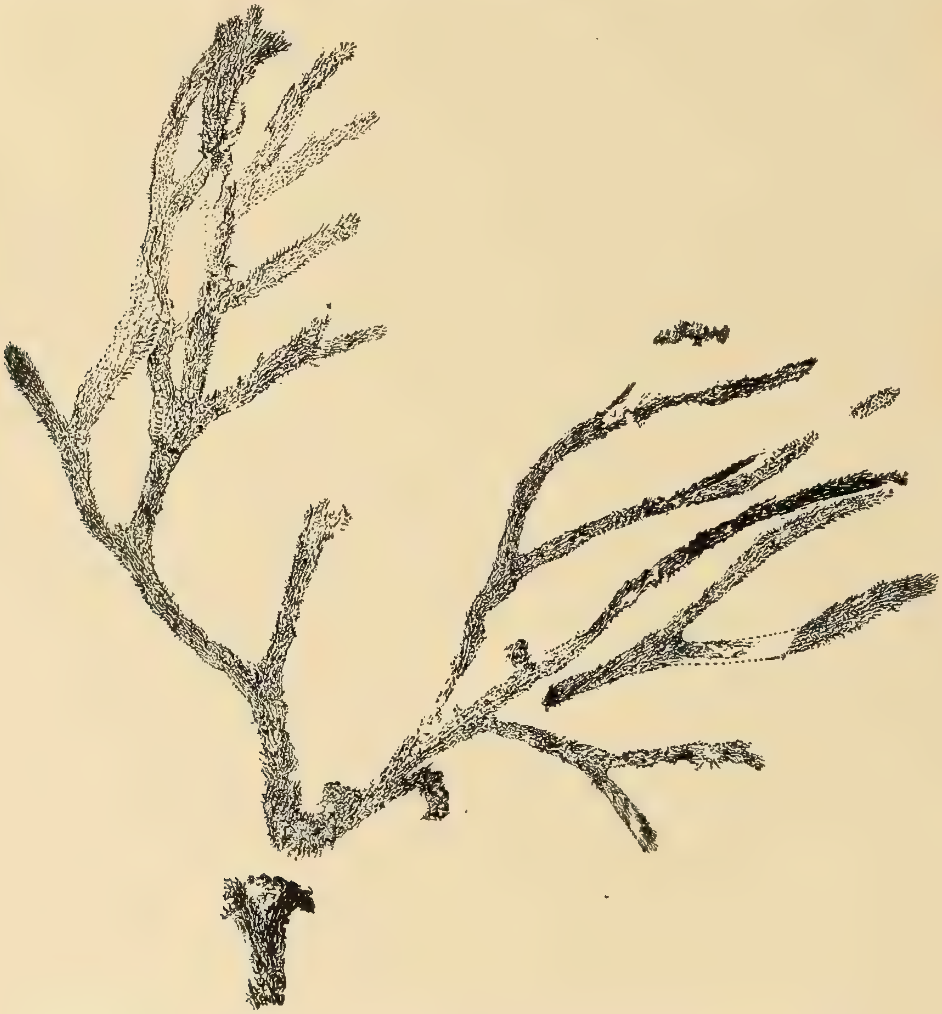

Fig. 93 Inocaulis plumulosus Hall. Rhabdosome from Niagaran of Hamilton, Ont. Original in National Museum. Nat. size

the thecae. Where in unweathered specimens the perisark is partly broken away (as in pl. 7, fig. 1), the circular sections of the composing tubes can be seen and the whole branch is found to be composed of apparently equal tubes.

The rhabdosome when more complete than in the specimens hitherto mentioned forms a dense mass of overlapping branches, which on account of the frequent dichotomies and later reapproachments of the branches assumes to some extent the aspect of a huge Desmograptus.

We have been unable to see in any of our or Spencer's rhabdosomes the central axis which he asserts to have observed in a number of specimens, and we doubt, from the general structure of this form, that such a thing as a central axis existed.

Inocaulis divaricatus Hall

Inocaulis divaricatus Hall. Alb. Inst. Trans. 1879. 10: 2. Abstract
Inocaulis divaricatus Hall. Geol. Sur. Ind. 11th Rep't. 1882. p.225; pl. 1, fig. 3
Inocaulis divaricatus Hall. Alb. Inst. Trans. 1883. 10: 58
Inocaulis divaricatus Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 565, 585
Inocaulis divaricatus Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 15, 35
Inocaulis divaricatus Gurley. Jour. Geol. 1896. 4: 99, 309

This representative species of the genus Inocaulis in the Waldron shale of Indiana is based on a fragment. From Hall's description and figure of the same, which have not been added to by later investigations, it can be inferred that I. divaricatus is nearly related to I. plumulosus; the large angle of divergence of the branches being the main difference. As Hall's figure indicates, the "projecting imbricating scales" of I. plumulosus are also present in this species, notwithstanding the statement to the contrary in the original description.

Inocaulis flabellum (Miller & Dyer) James

Licrophycus flabellum Miller & Dyer. Cin. Soc. Nat. Hist. Jour. 1878. 1: 25; pl. 2, fig. 4
Inocaulis flabellum James. Cin. Soc. Nat. Hist. Jour. 1885. p.164; pl. 9, fig. 8

This is no graptolite.

ACANTHOGRAPTUS Spencer

The genus Acanthograptus has been proposed by Spencer for two forms from the Niagaran of Hamilton, Ontario. He sees its diagnostic

feature in that "one side of the branches is furnished with prominent spines or denticles, which appear to mark the cell apertures," and compares it with Dendrograptus, stating as difference, that it is stronger and more bushy than species of that genus, and has conspicuous spines indicating a different cell structure.

Lapworth has later [1881] asserted its presence in Wales and Scotland, and suggested that Acanthograptus, if the denticles are horizontal, will be found to lie somewhere near Thamnograptus. Since these conclusions are based on Spencer's insufficient diagnosis it is quite possible that the British forms belong elsewhere.

Gurley adds in his manuscript to Spencer's diagnosis:

This is apparently a good genus, including several species which present a very similar facies, principally in the plumulose branches with a tendency to a 2 — or 3 — spicate termination. But if this genus be altogether distinct from Inocaulis (a point on which at present I do not feel positive), it is certainly here that Spencer's Inocaulis walkeri belongs.

The type of this group is A. granti, the first of the species described. The latter and several other hitherto undescribed species from Hamilton, present the extreme development not in numbers but in size of the "spines," and for this reason present an aspect quite different from that of I. plumulosus [*see* pl. 6, fig. 3, representing a fine specimen loaned to us by its collector, Mr Schuler in Rochester], but identical with that of Inocaulis suecica and I. musciformis Wiman. Since we have also observed in Canadian species of Acanthograptus a like composition of the spines of several emptying tubes [*see* pl. 7, fig. 4] as has been found in the Swedish, we can safely cite here the results of Wiman's important observations [*see* text fig. 94–96].

In A. suecicus which is the better known of the two species Wiman observed that the branches bear the branchlets which proceed alternatingly to the right and left in pennate fashion and consist each of four successively opening individuals. Only two of these are visible on figure 95, the other two opening on the reverse side of the branchlets. These four individuals belong to four different generations and they consist of two

thecae and two gonangia (the latter opening in the corners between the thecae on the reverse side of the branchlets). The "budding individuals," the third group of individuals do not empty to the outside and are hence not observable in an external view.

In the series of sections which we copy here from Wiman [text fig. 94] the separation of a branch with its four individuals and a budding individual at the lower end in figures F and G, are seen.

A. musciformis differs from A. suecicus in having a greater number of individuals in each branchlet.

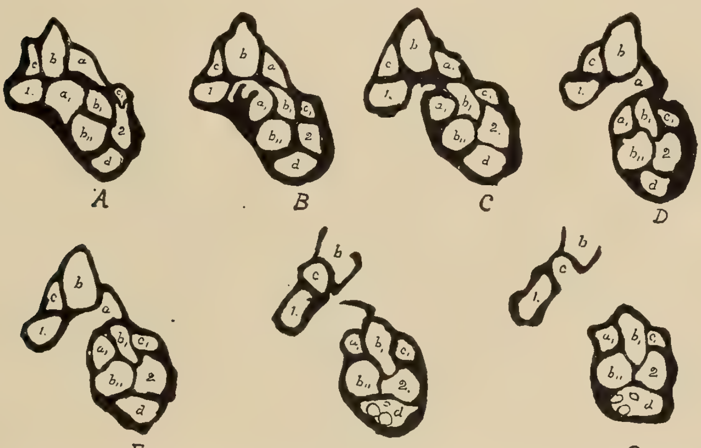

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Fig. 94 Series of thin sections of Acanthograptus suecicus (Wiman). The following table explains the lettering:

Generation	Gonangium	Theca	Budding individual
1	....	b	....
2	a	b,	....
3	e	1	....
4	a,	b,,	....
5	c,	2	d

Fig. 95 Acanthograptus suecicus (Wiman). Fragment of specimen

Fig. 96 Acanthograptus musciformis (Wiman). Branch. x 10

No individuals open on the branches of Acanthograptus but all individuals originate in them, in groups of three (designated as nourishing individual or theca, gonangium and budding individual), as the thin sections here reproduced show.

Acanthograptus is according to Wiman's observations a true genus of the Dendroidea, with a structure corresponding to that of Dendrograptus and Dictyonema. "The only difference between this species (A. sueci-

cus) and e. g. a Dictyonema consists in the fact that here the individuals are kept together for some time in order to empty afterwards in alternating groups."

In our form [*see* pl. 7, fig. 4] the branchlets are distinctly composed of a greater number of individuals (5–10) whose apertures become visible in somewhat weathered specimens. There may hence exist a still wider variation in the number of individuals emptying on the branchlets than Wiman found between his two species.

Počta has placed only forms with distinct "scales" under Inocaulis and by this safe proceeding excluded forms resembling Palaeodictyota anastomotica which have the general appearance of an Inocaulis but lack the projecting groups of individuals. But his forms are also more properly referred to Acanthograptus.

He distinguishes in the compressed material two sizes and forms of "scales" or lamellae, (1) very fine, scaly, closely arranged lamellae and (2) larger spiniform extensions, being placed on each side in alternating rows. The former are the individuals in the branches which in the compressed specimens produce by their divergence a characteristic scaly effect; and the latter the branchlets consisting of the emptying individuals.

Acanthograptus walkeri (Spencer)

Plate 6, figures 1, 2; plate 7, figure 4

Inocaulis walkeri Spencer. Can. Nat. 1882. 10: 165 (*nomen nudum*)

Inocaulis walkeri Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 585, 586; pl. 5, fig. 2

Inocaulis walkeri Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 14, 35, 36; pl. 5, fig. 2

Inocaulis walkeri Gurley. Jour. Geol. 1896. 4: 99, 309

The Rochester shale at Middleport, N. Y. has afforded four well preserved specimens of a form which by comparison with material of the Spencer collection from the Niagaran at Hamilton, Ontario, we have identified with this species.

Spencer's diagnosis is very brief and Gurley has carefully redescribed

the form in his manuscript. Our specimens tally completely with this description, which we publish in the following:

Polypary of general dendroid aspect; main branches mostly 1–1.5 mm thick, a width of 2 mm being only seen once, immediately below a bifurcation. Branching not very regular. Usually at the proximal end several branches are somewhat clustered and diverge thence radiatingly. On

97 98

Fig. 97, 98 Acanthograptus walkeri (Spencer). Enlargements (x 5) of portions showing the branchlets and thecal apertures. Originals from the Rochester shale at Middleport, N. Y.

one specimen, which I hardly feel able to separate, the branching is rather more from a main axis. The branches, especially the main ones, are thickly beset (spinose shaggy) with the long blunt, obliquely upward directed denticles, which are about 25 in the space of 25 mm. They differ much in appearance in different parts of the polypary, if indeed there are not more than one kind of them. Sometimes on the main stem they are blunter (about 1.0 mm long and 0.75 mm wide at base) while on the branches and branchlets they are less blunt. But on the main stem and

principal branches longer, narrower, and less rigid and regular and more hairy rootlike processes occur.

Horizon and locality. Ten specimens (including two in Spencer collection labeled Inocaulis walkeri and I. plumulosa) from Niagara formation and Niagara chert, Hamilton, Ontario.

This species can be told by the distinct and numerous "denticles" on both sides of stem and branches, finer and less blunt dentate than in A. granti.

Gurley refers this form, we believe correctly, to Acanthograptus [*see* his note under Acanthograptus, p. 192].

One of our specimens [pl. 6, fig. 1] recalls I. divaricatus Hall in its wide open mode of branching. The latter, also a Niagaran species, is, however, described as being 2 mm wide — and hence probably a coarser form — and as lacking the "projecting imbricating scales." The correctness of the latter statement is made doubtful by the original drawing, which distinctly shows the "scales" on the right hand branch.

CACTOGRAPTUS gen. nov.

Etymology. Κάκτος, a prickly plant; γράφω, I write.

A form from the Clinton shales above the lower iron ore bed at Clinton N. Y., suggests at first sight both Acanthograptus and Inocaulis, the former by its prominent "spines," the latter by the broad, little consistent appearance of the branches, but is found by closer study to differ so materially from both that it can not be properly placed with either. Its principal difference from both rests in the character of the "spines," which as a comparison of the enlargements of the genotype [*see* text fig. 99] with those of the genera here adduced will show are not finger-shaped and bearing apertures on all sides as in Acanthograptus and Inocaulis, but tubular, bluntly triangle in outline and of the form of large, simple thecae or "denticles." They possess a straight, obliquely ascending ventral or outer margin and a concave upper or apertural margin. These denticles have the form of those of species of Dendrograptus and Dictyonema, from which genera the habitus is, however, widely different. The broad middle portion of

the branches is as shown by the many parallel thecal walls composed of numerous thecal tubes as in Inocaulis and Acanthograptus.

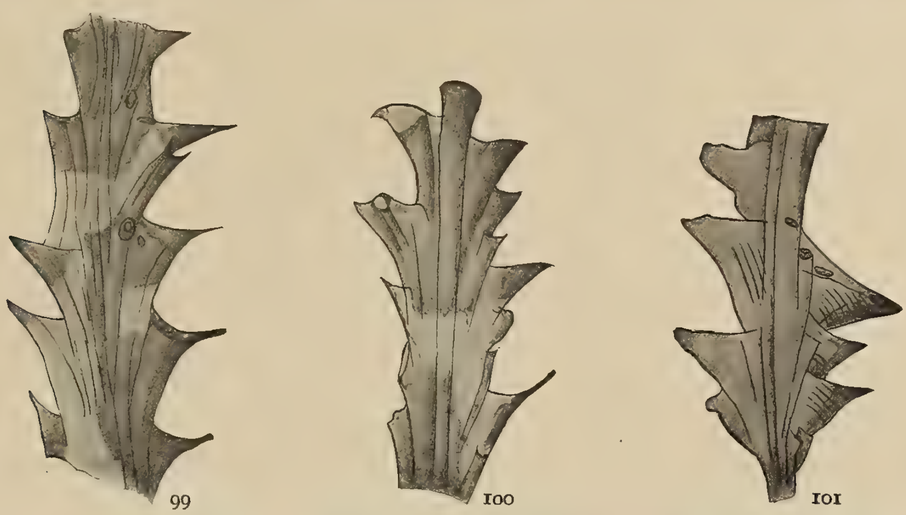
The diagnosis of the genotype is as long as the genus remains monotypic, that of the genus.

Genotype. Cactograptus crassus sp. nov.

Cactograptus crassus sp. nov.

Plate 8, figure 1

Description. Rhabdosome bushy, consisting of numerous thick branches, which are gently and irregularly bent and bifurcate at long intervals. The basis of the rhabdosome is not known. The (fragmentary)



99 100 101

Fig. 99–101 Cactograptus crassus sp. nov. Fig. 99 Enlargement (x 5) of portion of branch showing the form of the spines. Fig. 100 shows the terminal part of a branch; fig. 101 suggests the spiral arrangement of the spines

rhabdosome of the type specimen is 90 mm long and 25 mm wide. The branches are 3.5 mm wide measured between the tips of the denticles, and still 2 mm between the interthecal notches, and distinctly striated longitudinally. The denticles are triangular, bracketlike in shape. They overlap about one half their length, are apparently arranged in a long slender double spiral, number, in the compressed specimen, 8 in 10 mm on either side of the branch, are inclined with their outer margin 20° to the axis of the branch, while their apertural margin which is gently concave, is nearly

normal to the main direction of the branch and continued into an apertural spine.

Position and locality. In the dark greenish Clinton shale overlying the lower ore bed at Clinton, Oneida co., N. Y.

Remarks. Notwithstanding their great width, the branches seem to have been very little resistent for they are completely flattened out in a layer where all the associated small lamellibranchs and brachiopods have preserved their original form fairly well. The light color and obvious tenuity of the carbonaceous films are further proof that there has been very little substance and strength to the walls.

The branches in the type specimen are not spread out on the surface of a single layer but all separated by thin layers of shale and extending in various directions into the rock so that it becomes obvious that the original form of the bush was rather scraggly and that it contained more branches than are shown in the figure.

PALAEODICTYOTA Whitfield, emend. Ruedemann

Dr Ringueberg [1888, p.131] has referred a species from the Rochester shale to Inocaulis (I. anastomoticus) stating at the time that he did so with some hesitancy because his form is provided with anastomoses or reticulations of the branches while Inocaulis is loosely branching and adding: "Still the character of the branches so closely resembles those belonging to this genus that I am constrained to place it here." We have no doubt from the absence of the anastomes in some parts of the rhabdosomes and their presence in others [*see* pl. 6, fig. 4; pl. 7, fig. 6] that they should not be given too much weight in generic distinction, although they give the species here under consideration a most characteristic aspect and may indicate a definite growth tendency which requires recognition; and indeed has found it in being made the criterion of distinction between Desmograptus and Dictyonema. But it becomes evident from a closer comparison of the branches of Inocaulis plumulosus and I. anastomoticus that also an important difference appears in these, notwithstanding their general similarity

which is due to their like composition of many tubes. This difference consists in the absence of the spines or "scales" forming so prominent a feature in Inocaulis and Acanthograptus; the tubes as a rule emptying directly on the surface of the branches in Palaeodictyota. The difference may also be but one of grade since there are all transitions possible between the highly projecting bundles of emptying tubes in Acanthograptus and the flat apertures in Palaeodictyota anastomotica, but it is certain that the combined tendency to anastomosis of branches and the lack of development of the spines produce a type of structure markedly different from that of the typical Inocaulis. We consider accordingly the combination of these two characters as typical of the genus.

Professor Whitfield [1902] recognizing from specimens of Ringueberg's species in the American Museum of Natural History the great difference of habitus between that form and the genotype of Inocaulis, has proposed to place I. anastomoticus among the algae[1] and erected the genus Palaeodictyota (in allusion to the recent alga Dictyota) for its reception. On the supposition that I. anastomoticus is a synonym for I. ramulosus Spencer, the latter is named as genotype of the new genus. I. anastomoticus is, however, as undoubtedly a graptolite as its associates in the Rochester shale, and distinctly shows in our well preserved specimens the composition of its branches of tubular thecae [*see* pl. 7, fig. 6]. Further, I. anastomoticus and I. ramulosus are not identical, as the writer had occasion to convince himself by comparison of authentic material[2] and are specifically if not generically different, Spencer's species lacking the frequent anastomoses and possessing fringed margins. It thus happens that Prof. Whitfield cites as genotype I. ramulosus while

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[1] "The organism is so unlike Inocaulis that I have considered it more natural to place it among the marine algae, but finding no genus of fossil alga that will correspond to it, I have concluded to propose for it the new name Palaeodictyota from its strong similarity to the living form Dictyota Lamereux."

[2] Dr Gurley in his revision of the graptolites from the Niagaran rocks of Hamilton, where both species occur, also distinguishes both forms and compares I. ramulosus with Acanthograptus granti.

specimens of I. anastomoticus are used as illustrations of the genus. Since, however, it is obvious that the Lockport specimens led to the erection of the genus and the description of the latter is based on these, the term Palaeodictyota, though a misnomer, can be given validity by amending the genus with P. anastomotica as genotype.

Because it lacks the spines entirely we have placed here also Inocaulis bella Hall and Whitfield, although in the few fragmentary specimens known it fails to show any anastomoses. We have, however, a form from the Clinton iron ore of New York which undoubtedly is an ancestor or earlier mutation of Inocaulis bellus and which, while in the distal parts of the branches possessing like loose branching, exhibits distinct anastomoses more proximally and leaves no doubt that also the free distal portions of its branches which are exactly like those of Inocaulis bella would eventually have been reunited into a desmograptoid meshwork.

Genotype. P. anastomotica (Ringueberg)

Palaeodictyota anastomotica (Ringueberg)

Plate 6, figure 4

Inocaulis anastomotica Ringueberg. Acad. Nat. Sci. Phil. Proc. 1888. p.131, 132; pl. 7, fig. 2, 2a

Inocaulis anastomotica Gurley. Jour. Geol. 1896. 4: 99, 308

Palaeodictyota ramulosa (Spencer) Whitfield. Am. Mus. Nat. Hist. 1902, v. 16, art. 30, p.399, pl. 53

This important graptolite of the Rochester shale has been carefully described by Dr Ringueberg. The following is the original description:

Frond flabelliform or possibly circular or cyathiform in the perfect state.

It is composed of large coarse branches, the principal ascending ones of which are from 2 to 3 mm in width, with smaller lateral branches and tips. Whole frond united by frequent anastomoses into an irregular network. The branches seem to anastomose as frequently by the growing towards each other of two adjacent branches; these unite whenever they chance to meet into a common branch, which grows upwards and bifurcates as before; as by the more slender diagonal connecting filaments.

By reason of this peculiar mode of growth no single branch can, as a

rule, be traced for any considerable distance as maintaining its identity, for as it bifurcates each bifurcation is often met by that from the adjoining two branches and they, by uniting, form a single branch; at the outer margin the branches taper down and terminate in from two to more sharp points, or serrations.

Surface of the branches marked by strong, irregular longitudinal wrinkles, which at times seem to assume a semiscabrous character. Margins of branches rarely present a slight serration or roughness; and in places where portions of the black corneous branches have scaled off the cast shows the obverse side to have the same character as the other.

The openings in the network are of various sizes and shapes but mostly oval or fusiform, no two being alike.

The type specimen presents about one third of the circumference of a circle and measures 9 cm from the margin to as near the center as is preserved and which judging from the angle of radiation of the branches could not be more than 1 cm further.

There is some hesitancy in placing this species in this genus because all the forms which we are acquainted with are rather loosely branching with few if any anastomoses or reticulations. Still the character of the branches so closely resembles those belonging to this genus that I am constrained to place it here.

102

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Fig. 102, 103 Palaeodictyota anastomotica (Ringueberg). Fig. 102 Copies of original figures. Fig. 103 Fragment of rhabdosome from the Rochester shale at Middleport, N. Y.

From the lower third of the shale at Lockport ranging as high as the Homocrinus band.

Only two fronds have been found in which the margin is preserved, and both seem to represent portions of a quite regular circle.

Ringueberg's figures, though representing but a small portion of the rhabdosome, are correct and expressive of the characteristic appearance of the form. We have inserted them here and further illustrated the form by the tracing of a nearly perfect specimen [pl. 6].

Dr Ringueberg collected his types from the lower third of the shale at

Lockport. The State Museum has a good series of specimens from the lower third of the Rochester shale at Middleport. At the latter locality it is one of the common forms and associated with Dictyonema retiforme, D. gracile, D. polymorphum and Inocaulis plumulosus. A close relative of this species (P. clintonensis) is here described from shale accompanying the Clinton iron ore.

Our Middleport collection permits us to give the following additional data:

The rhabdosome, when compressed vertically, assumes the form of a circle, being about 10+ cm in diameter; originally it was infundibuliform or cyathiform. In its lower part the wall of the cup or funnel was formed by an approximately regular desmograptoid reticulation, toward the margin the branches became more bushy and left the surface of the cup as is shown by the frequent overlapping of branches and along the growing margin numerous bispicate extremities are seen.

The thickness of the branches varies from .6 mm to 1.8 mm and may be said to be typically a little more than 1 mm; the meshes are long elliptic, numbering three to five, mostly four, in the space of 10 mm transversely and vary in length from 3–8 mm, being typically about 5 mm long. The branches are mostly reduced to a smooth, structureless film, but in some portions the fibrous structure resulting from the composition of tubular thecae is distinctly seen. Their margins are smooth and the thecal apertures hardly, or not at all, projecting.

Dr Ringueberg expresses some hesitancy in placing his species in Inocaulis giving the character of the branches as his reason for referring it to that genus and the reticulations or anastomoses as a differing character. We have discussed the relations of Inocaulis to other genera before arguing there that by reference to the genotype I. plumulosus only forms with distinct projecting bundles of thecae along the margins, could be properly referred to that genus. P. anastomotica has, however, quite probably the normal thecae of a Dictyonema. We might add that the nearest form to this in general appearance is a Siluric species of Bohemia that has also been referred to Desmograptus and not to Inocaulis by Počta

Palaeodictyota clintonensis nov.

Plate 6, figure 5; plate 7, figure 5; plate 8, figure 3

Mr Hartnagel while engaged on an investigation of the iron ores of the Clinton formation obtained in the ferruginous shale that directly overlies the ore a few small but finely preserved fragments of a graptolite that is apparently closely related to P. anastomotica. Later collections have shown this form to be not uncommon above the lower iron ore bed at Clinton, N. Y.

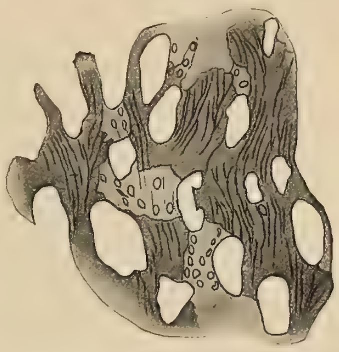

Fig. 104 Palaeodictyota clintonensis sp. nov. Enlargement (x 5) of portion of rhabdosome, showing the thecal apertures

The main difference is one of relative dimensions, the Clinton form having narrower branches (.4 mm–1 mm, mostly only about .5 mm) and smaller meshes (five to seven in 10 mm transversely and three to four longitudinally). The meshes are also relatively wider and shorter.

Palaeodictyota bella (Hall & Whitfield)

Plate 3, figure 7

Inocaulis bella Hall and Whitfield. Pal. O. 1875. 2: 122; pl. 6, fig. 2

Inocaulis bella Spencer. Can. Nat. 1875. 8: 458

Inocaulis bella Spencer. Can. Nat. 1882. 10: 165

Inocaulis bellus Spencer. Acad. Sci. St Louis. Trans. 1884. 4: 564, 585

Inocaulis bellus Spencer. Mus. Univ. State Mo. Bul. 1884. 1: 14, 35

aff. Inocaulis bellae Lindström. List. foss. faunas Sweden II. 1888. p.22

aff. Inocaulis bellae Holm. Bih. till K. Swensk. Akad. Handl. 1890. v. 16, no. 7, p.4

Inocaulis bellus Gurley. Jour. Geol. 1896. 4: 99, 308

Inocaulis bellus Gurley ms.

Hall's description of this species is based on a single specimen.

Gurley makes the following remarks:

I am indebted to Prof. Edward Orton for the loan of the type specimen of this species. After careful comparison with it of Hall's description and figure I can not find that either leaves much to be desired. Only one correction should be made. The strongest branches reach a width of 1 mm (0.04 inch), whereas Hall says that 0.03 inch is the greatest width attained.

He adds that "one specimen occurs in the collection from the Niagara shale, Hamilton, Ontario." The latter is a beautifully preserved specimen, retaining the thecal tubes in a pyritized condition. We reproduce here [pl. 3] a drawing of the type from a photograph and camera enlargements of parts of the Ontario specimen to show its characters in detail. The margins of the branches are distinctly smooth, only in one place a few thecae are seen [*see* fig. 107]. They are narrow and so appressed to the branch that they hardly project. For this reason we do not believe that this form can be considered as congeneric with I. plumulosus and that Inocaulis is the proper receptacle for it, although by the width of the branches and their composition of many fine tubular thecae its close relation to that genus is indicated. We place it, for the present, with Palaeodictyota.

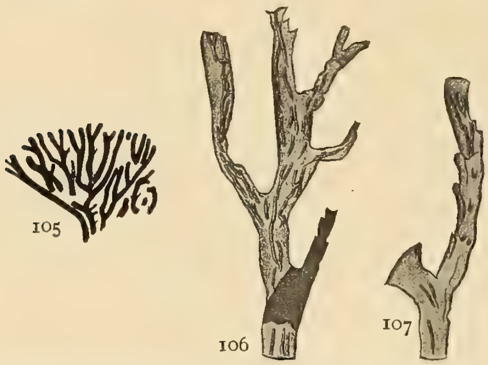

Fig. 105–7 Palaeodictyota bella (Hall & Whitfield). Natural size drawing and enlargements (x 5) of fragments of a specimen from the Niagaran of Hamilton, Ont.

Palaeodictyota bella (Hall & Whitfield) mut. **recta** nov.

Plate 6, figure 6; plate 7, figure 6

The shale adjoining the Clinton iron ore contains rhabdosomes of a form which appears to be so little different from P. bella — at least with the incomplete material at present available of both forms — that we prefer to designate it as but mutationally different from the Rochester shale type of P. bella. Its dimensions, notably the thickness of the branches are the same as in P. bella, but its habitus is a little more erect or less scraggy, owing to slightly smaller angles of divergence of the bifurcating branches and somewhat greater intervals of bifurcation.

THAMNOGRAPTUS Hall

The genus Thamnograptus, erected in 1859 [Pal. N. Y. v. 3] by Hall for two forms of the Normanskill shale, has ever since remained among

the doubtful genera of graptolites, since no thecae or apertures on the branches have been observed. The fact that forms properly referable to this genus were rarely found, aided greatly to keep it in mystery. The only one who advanced our knowledge of the genus was Lapworth, and his observation that Rastrites barrandii Hall is a branch of Thamnograptus added another peculiar character, that of a one sided branching, to the curious group. The original diagnosis of the genus is:

Bodies consisting of straight or flexuous stipes (simple or conjoined at base ?) with alternating and widely diverging branches; branches long, simple or ramose in the same manner as the stipe. Substance fibrous or striate; the main stipe and branches marked by a longitudinal central depressed line, indicating the axis. Cellules or serratures unknown.

The rather large collections which we have gathered from various outcrops of the Normanskill shale, have furnished us material that not only fully verifies Lapworth's observation of the identity of Rastrites barrandii with Thamnograptus, but also demonstrates the identity of T. typus and T. capillaris, the two Normanskill species distinguished by Hall [*see postea* p. 209]. Thereby the complicated system of branching of a Thamnograptus becomes known.

T. typus and T. capillaris are shown here [*see* p. 208] to be the main stipe with its stripped-off branches of the first order, the former representing the proximal portion of the rhabdosome, the latter the distal one, while the branches of the higher orders are represented by Rastrites barrandii. Furthermore, sections of T. typus and specimens of "Rastrites barrandii" have been observed, which exhibit a distinct thecal composition [*see* pl. 12, fig. 9, 13, 14]. It is seen in these that the thick stipe of T. typus must have originated from a series of slender tubular thecae which have become enveloped by thick secondary conchiolinous layers and that the "Rastrites" form consists likewise of a series of slender tubular, slightly curved thecae with but little projecting apertures which all lie on one side of the branch, and from the lower margins of which again very long, hairlike branches proceed that as a rule are broken off at a short, uniform distance. Whether these again are composed of thecae has

not been established. When complete, the stem of the genotype T. typus is surrounded by an inextricable mass of tufts of such finer branches.

No indications of a more complex composition of the branches of different types of thecae, such as found in Dendrograptus, have been noticed. But even if these apparently simple thecae are indeed of more complicate structure, the species is still so distinctly different in its general mode of growth and the form of the thecae from Dendograptus *s. str.* that it represents a good genus. It is by the same characters equally well separated from Mastigograptus.

Nemagrapsus capillaris Emmons is but a drifted and macerated distal portion of a T. typus, but being described and named before the other parts, the name has precedence over the others.

The genus as now known would comprise:

T. capillaris *Emmons* (+T. typus+ T. barrandii)	T. affinis *Whiteaves*
T. scoticus *Lapworth*	T. anna *Hall*

The latter species is from the Point Levis shales of Quebec. Perhaps also Ptilograptus tenuissimus Rued. from the uppermost zone of the Deepkill shales would be more properly referred to this genus than to Ptilograptus, but both T. anna and Ptilogr. tenuissimus can not be safely placed here before their distal mode of branching and their thecal structure are known. Also of T. scoticus and T. affinis only the stipes with the bases of the main branches of the first order are known.

Thamnograptus capillaris (Emmons)

Plate 10, figures 4–8; plate 12, figures 9–16

Nemagrapsus capillaris Emmons. Amer. Geol. 1855. v. 1, pt II, p.109; pl. 1, fig. 6

Thamnograptus typus Hall. Pal. N. Y. 1859. 3: 519, fig. 1, 2

Thamnograptus capillaris Hall. *Ibid.* p.520, fig. 3

Rastrites barrandi Hall. *Ibid.* p.521, 522, fig. 1, 2

Thamnograptus capillaris, T. typus, Rastrites barrandi Walcott. Geol. Soc. Am. Bul. 1890. 1 : 338

Thamnograptus capillaris, T. typus, Rastrites barrandi Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets 1879, p.35)

Thamnograptus typus Nicholson. Mon. Brit. Grapt. 1872. p.131, fig. 71

Thamnograptus barrandi Gurley. Jour. Geol. 1896. 4: 88

Thamnograptus typus and Th. barrandii Lapworth. Cat. West. Scott. Foss. 1876. p.7; pl. 4, fig. 95, 96

Thamnograptus typus? Lapworth. Belfast Nat. Field Club Rep't & Proc. 1877. v. 1, Apx. p.143; pl. 7, fig. 16

Thamnograptus barrandii Lapworth. Roy. Soc. Can. Trans. Sec. 4. 1886. p.178

? Thamnograptus typus T. S. Hall. Australasian Ass'n Adv. Sci. 1893. p.1 of sep. copy

Thamnograptus typus Clark. Geol. Mag. 1902. Ser. 4, 9: 498

Description. Rhabdosome large (distal portion, representing obviously but a small part of the whole stock, measuring 110+ mm), consisting of a straight or slightly zigzagged main stipe and numerous orders of branches, those of the first order being arranged in alternating order, directed subhorizontally and 3 mm–5 mm apart; those of the later ones arranged on one side of the mother branch, and but 1.5 mm apart. The complete rhabdosome is surrounded by a dense mass of hairlike branches. The main stipe and the older branches attain a width of 1.6 mm, the distal branches but .1 mm. The main stipe and the branches of the first order are composed of very slender, tubular, frequently curved thecae which overlap nearly one half their length, have but slightly projecting apertures with a small apertural mucro and number five to six in the space of 10 mm. From the proximity of their apertures proceed the extremely delicate branches of the higher orders, whose structure has not been made out. Sicula not observed.

Position and localities. Hall's types were collected in the Normanskill shale at Kenwood near Albany. Other specimens have been obtained in the same horizon at Glenmont near Albany, on Mount Moreno and at Stockport ("Nemagrapsus capillaris"). This species is, therefore, while nowhere common, apparently a constant element of the Normanskill fauna. Lapworth has also recognized it in the Glenkiln shales of Scotland and in Ireland. The T. typus of Victoria, Australia is associated with forms of the Deepkill shales and doubtful.

Remarks. I have here united forms which have passed under three different generic and four specific names, although in part the evidence is only indirect. Rastrites barrandii has been recognized as a Tham-

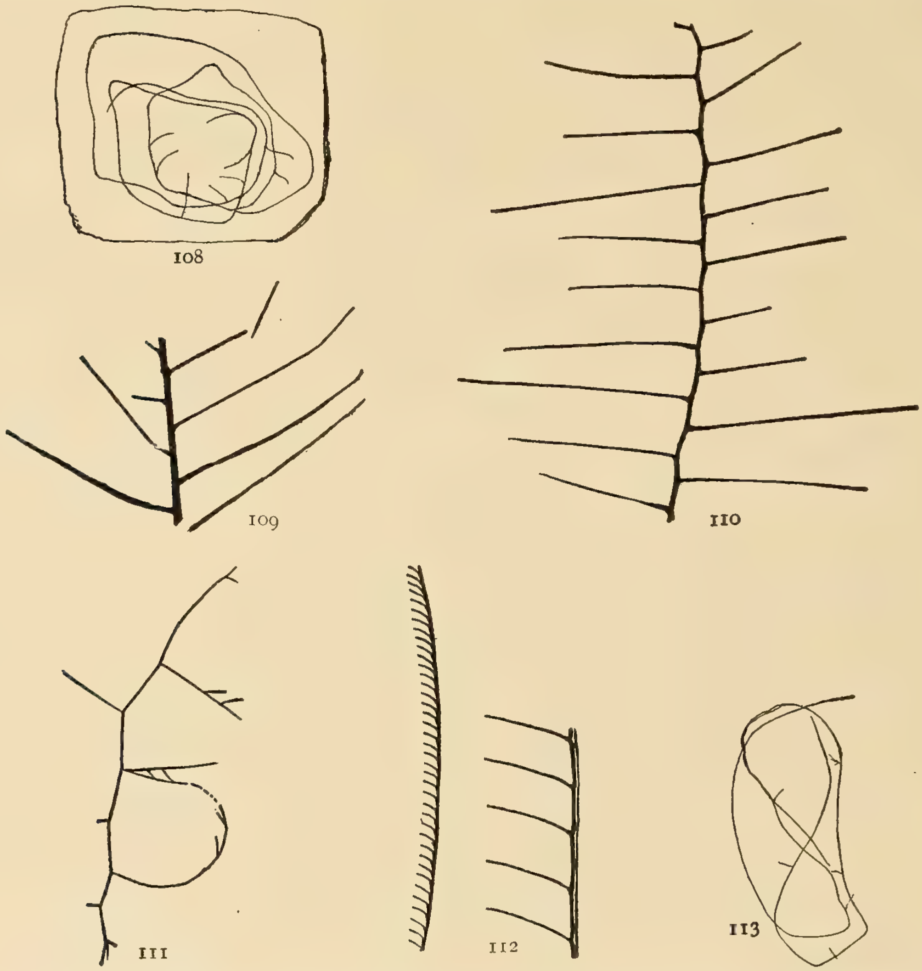

Fig. 108–13 Thamnograptus capillaris (Emmons). Fig. 108 Copy of Emmons's original figure of Nemagrapsus capillaris. Fig. 109, 110 Copies of Hall's figures of Thamnograptus typus. Fig. 111 Copy of Hall's figure of Thamnograptus capillaris. Fig. 112 Copy of Hall's figure of Rastrites barrandi. Fig. 113 Drawing of Nemagrapsus capillaris from Stockport, N. Y. by Gurley. (x 2)

nograptus by Lapworth and been found directly attached to stipes of T. capillaris Hall, by the writer [*see* pl. 10, fig. 7]. The latter form, though differing much in its finer habitus from T. typus, is still connected to it by intermediate fragments, which show that all are parts of the

same large rhabdosome that greatly changed in thickness from the base to the last extreme branches.

Hall describes his species T. capillaris without any intention of identifying it with Emmons's Nemagraptus capillaris. The latter species, however, is, in the writer's conviction — founded on the study of typical material from Stockport which Gurley had identified with Nemagraptus capillaris — based on drifted terminal fragments of the rhabdosomes which on account of their great delicateness have become rolled up, and retaining but the basal portions of a few of their branches have acquired an entirely different aspect [*see* text fig. 113]. The specimen [pl. 10, fig. 7] could be readily imagined to become reduced to the form of figure 113.

The Rastriteslike aspect of the secondary branches [*see* pl. 10, fig. 6, 7] is due to the regular breaking off of the extremely thin branches of the third order at a certain uniform distance from their bases. The fact of this frequent equidistant breaking off of the finer branches seems to indicate a jointed structure which again is suggestive of their composition of thecae; but the latter could not be made out. Where these finer branches are preserved, the rhabdosome is wrapped in a hairy mass [*see* pl. 10, fig. 5, 8] of such density that it mostly defies the discerning of the coarser branches. These amazingly dense masses of fibers are frequently also drifted into spiral masses as "Nemagraptus capillaris." "T. typus" and "T. capillaris" are hence only the skeletons of more complex structures.

The main stipes and branches derive their greater coarseness not from a composition of many thecal tubes such as is found in Dendrograptus, Dictyonema and Inocaulis but from the deposition of secondary strengthening layers. In stipes broken through the center the original thin stipe ("T. capillaris") is still preserved as a narrow canal [*see* pl. 12, fig. 14, 15, 16] from which the branches diverge at right angles. The thick wall shows its origin in fine longitudinal growth lines. The apertures of the

oldest thecae seem to have become completely buried in the thick peridermal layers [*see* pl. 12, fig. 14 at a].[1]

The thinner branches, on the other hand, exhibit at their surface the normal transverse growth lines [*see* pl. 12, fig. 13].

The branches of T. typus have not shown any trace of the presence of several thecal tubes at the same level of the branch or of the existence of thecae with different functions. It is, however, possible that such nevertheless existed within the simple tubes now alone visible and that they were separated by walls of such thinness that these are not observed in the compressed material. Perhaps the presence on several specimens [*see* pl. 12, fig. 10–12] of strong nodes having the appearance of joint knots to whose nature the writer has not been able to find any clue, will some day be connected with a function of the thecae different from the purely nutritive one, possibly a reproductive (gonothecal) one. The nodes appear to be more or less spherical swellings of the apertural portions of some of the thecae, for they show a large, round aperture. On the other hand they are irregularly distributed along the stems and may have been of merely parasitic origin.

The specimens from the Upper Arenig of St Davids, Wales, identified by Hopkinson and Lapworth with Emmons's species, are probably not correctly placed, notwithstanding their extreme general similarity to "Nemagraptus capillaris," for they are described as consisting of several principal branches diverging in approximately opposite directions from a central point.

MASTIGOGRAPTUS gen. nov.

Hall described his genus Dendrograptus as characterized by "a broad spreading shrublike frond" and by cellules, that appear "sometimes as

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[1] It must have been such thickened stipes which Gurley had before him when he described the thecae of T. barrandii [1896, p.88] as follows: "A single specimen shows, scalariform-wise, the thecal mouth openings. They occupy about two thirds the width of the stem and are in the proportion of 25 to 25 mm. The aspect of the stem seems to oppose the view that the thecae project as in other genera from a coenosarcal canal. They appear rather to have been excavated out of the substance of the branch."

simple indentations on the surface, and sometimes distinctly angular, with the denticles conspicuous;" adding that "in some specimens the cellules are indicated by prominent pustulelike elevations, arranged along the center or in subalternate order on one face of the branch." Corresponding to the wide compass of this description a great variety of forms has, in the course of time, been brought under Dendrograptus. We have already in Memoir 7 pointed out that it has become the receptacle of all arboriform graptolites and that the fact of the great difference of the thecal apertures mentioned by Hall, indicates its heterogeneous character.

We have now before us a form (M. tenuiramosus) from the upper graptolitiferous beds which while originally described as a Dendrograptus and also properly referable to that genus as originally diagnosed, shows a structure totally different from that of the genotype of Dendrograptus (D. hallianus Prout) and at the same time is representative in its general habitus of a large group of the forms brought under Dendrograptus.

Dendrograptus hallianus has distinct "denticles," i. e. projecting thecae of the appearance of those of Dictyonema and Wiman has shown that also the internal structure of similar denticulate Swedish forms is as complex as that of Dictyonema. D. tenuiramosus, however, while arborescent in its habit, has smooth whiplike branches, which as Walcott has correctly observed, in the great number of specimens found in the Utica shale of Holland Patent, N. Y., exhibit nothing but a row of obscure pits, apparently the thecal apertures. The same is the case with the associated D. simplex and with other species of Dendrograptus. Dr Ulrich, however, has obtained material of a Dendrograptus in the Eden shale in Kentucky which he has, as I believe, correctly referred to D. tenuiramosus and which in beautiful preservation exhibits additional features [*see postea*] thereby revealing a structure entirely different from that of D. hallianus and the forms investigated by Wiman. We believe therefore in the necessity of separating these forms generically from Dendrograptus and in restricting the latter genus to species with distinct denticles.

The specimens here referred to are preserved in an extremely fine-grained, greenish gray shale in which the jet-black branches of the graptolites become very distinct by color contrast. To these branches are attached in great number brown elongate triangular appendages [*see* pl. 11, fig. 1–4] which clearly were conical in shape originally. Their lighter color is obviously due to greater thinness of the perisark and from the fashion in which the black branches are at their broken ends continued into brown shreds of like brown color, it would appear that the conical bodies are formed by but one or few of the perisarcal layers. They exhibit distinct transverse lines of the appearance of growth lines [*see* pl. 11, fig. 2] and a very sharp dark outline except at the distal margin where the supposed aperture is situated. The proximal end is distinctly contracted into a narrow tube with thicker wall. This in the best preserved specimens possesses two opposite lateral notches for the insertion of smaller conical bodies which sometimes are also preserved [pl. 11, fig. 4], consist of like brown substance and bear like growth lines. The larger conical bodies were in such numbers attached to the branches that in some places [pl. 11, fig. 1 at a] they form closely arranged series. From the great number of such bodies found loose on the Covington slabs and the fact that they are missing altogether on the numerous large rhabdosomes from the shales at Holland Patent, it is to be inferred that they were very easily detached and lost.[1] The explanation for this is found in their extremely small base of attachment and the probable presence of a joint at the latter; for not only do they always detach at this point, but it is also quite evident that the basal tubes were attached directly over the pores observable in the branches from which the appendages have been stripped, and that the walls of these pores do not appear rough, but smooth.

What are these conical appendages?

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[1] A typical specimen of M. tenuiramosus from the black Lorraine shale at St Bruno Mountain, Co. Chambly, Quebec, sent to the writer for identification by Professor Whiteaves, showed at first glance no trace of these bodies, but a smaller branch could be uncovered which retained them in a fine state of preservation.

It can be first stated that while the rhabdosomes in habitus and occurrence are distinctly graptolitic, there are no appendages known from other graptolites which could be compared in form to these cones. But by recourse to the living hydrozoans, two alternatives can be suggested, viz; that they were either normal thecae of nourishing individuals or gonangia (gonothecae).

In regard to the first hypothesis it can be said that this type of thecae would be more similar to the hydrothecae of the hydrozoans than any other of the graptolites; first by the basal constrictions, second by the presence of the paired appendages. It has repeatedly been pointed out as an important difference between the graptolites and the hydrozoans that in the latter the point of communication between the hydrotheca and tube of the hydrocaulus is more or less constricted and in the graptolites the theca is in uninterrupted continuous communication with the coenosarcal canal. Allman [1872, p.369] has for this reason compared the thecae of the graptolites to the nematocalyces and considered the graptolites as "morphologically plumularians in which the development of the hydrothecae had been suppressed by the great development of the nematophores." When it is further noticed that in general habitus also the Dendrograptidi approach more to the hydrozoans than any other graptolites (as noted before by Hall, Allman, Frech and others), the possibility that this form may point the way to the recent hydrozoans can not fail to suggest itself. I learn from Dr Ulrich that he also, on finding the material, at once recognized its great similarity to the Sertularians and its possible phylogenetic importance.

The first hypothesis is further supported, at least apparently, by the fact that while in other graptolites distinct thecae or receptacles for the zooids are visible as denticles on the branches, the form bearing these appendages appears to possess nothing but extremely slender, uniformly thin branches with circular pits and to lack all indications of a composition of separate tubes such as are found in Dendrograptus and Dictyonema.

The extreme thinness and complete compression of the branches leave one unfortunately in doubt as to their internal structure, especially in regard

to their possible composition of several tubes. All one can make out in this regard is a depressed central line in the thicker branches which as a rule, ends in the circular pits seen just below the bases of the secondary branches, giving one the impression of a closer structural connection between the central line and the pits and branches [*see* pl. 12, fig. 1].

In M. simplex [*see* pl. 12, fig. 5] these relations are a little clearer and it can be observed there that each component tube extends from the base of one branch to the second following, passing then out into the branch. It is hence possible that the thin, smooth filiform branches were not as simple in structure as they appear externally. Moreover, the type of M. arundinaceus (Hall) shows indications [*see* pl. 12, fig. 6 at b] that the pits were not arranged on one side (the "celluliferous side") only but were alternating on both sides. This is also suggested by the relation of the pits to the branches in M. tenuiramosus and M. simplex; on some branches the pits are found closely below the bases of the branches [*see* pl. 12, fig. 5], in others [pl. 12, fig. 4] in the middle of the internodes. This observation, if correct, may also indicate some complication in the structure of the branches. The supposition that the branches of M. tenuiramosus were of composite thecal structure is, of course, antagonistic to the hypothesis that the appendages were the thecae of nourishing individuals, for assuming the latter case we can not well escape the further conclusion that the branches, and the whole rhabdosome for that matter, as the bearers of the thecae represented nothing but a large continuous "funicle" corresponding to the hydrocaulus of the hydrozoans and Mastigograptus acquires then a structure and position entirely apart from the other Dendroidea.

The extremely slender and thin form of the branches which is so little suggestive of their composition of thecae requires the assumption of exceptionally thin and long thecal tubes. But this can not be considered as fatal to the conclusion of the composite character of the branches, since we have here shown that another genus, Thamnograptus, with similar thin whiplike branches is distinctly composed of long, tubular thecae.

The other alternative that the appendages were gonothecae is opposed by the presence of smaller paired cones on their bases; for these could be readily compared in form and position to the nematocalyces of the recent hydrozoans but would not be represented by analogous structures on the gonangia; and the regular and close arrangement of the appendages would seem to correspond altogether more to that of thecae than of gonothecae. But since we have seen above that the assumption of the function of these cones as thecae has as a corollary that of the function of the entire rhabdosome as a hydrocaulus, and all indications point on the contrary to the composition of the rhabdosome of tubular thecae it seems dangerous to press the analogy of the form with the recent hydrozoans too closely and give the general appearance and arrangement of the appendages too much weight. It would also seem that the extremely loose fixation of the conical bodies, indicated by their more frequent detached occurrence and the very rare observation of rhabdosomes bearing them, is more suggestive of their functional connection with the generative process than with any other.

While at present only one species, the genotype of the proposed genus, is known to bear the free, detachable thecae, other species, as the associated Dendrograptus simplex, possess identical smooth, flexible branches without indications of thecae and no doubt bore like appendages on them when complete.

To the genus Mastigograptus, as defined by the character of its genotype, can be safely referred Dendrograptus simplex Walcott and D. gracillimus (Lesq.) since both possess like smooth capilliform branches with rows of pits and occur in the same beds. There is also little doubt that numerous other species now referred to Dendrograptus, as D. serpens Hopk. and some of the older equally slender forms described by Hall from the Quebec region in which but slight indentations were observed as indications of thecae, belong here.

The relations of the genus Mastigograptus to several other genera also based on forms with capilliform or at least very slender branches with pits for "thecal apertures" are still obscure, mainly on account of our

incomplete knowledge of their structure. Such genera are Thamnograptus Hall, Phycograptus Gurley and Strophograptus Ruedemann. The genus Thamnograptus has by means of some excellently preserved specimens been found not to differ materially from other graptolites, in the composition of its branches of thecae which successively bud in single series [*see* pl.9, fig. 13]. Phycograptus is described by its author as distinctly segmented, but as shown by the present writer [*see* p.245] probably based, in part at least, on infrequent states of preservation of other forms, hence very doubtful in its validity and character. Strophograptus finally has been erected [1904, p. 716] for long capilliform, unbranched pitted fibers found in dense bundles in the older graptolite rocks. It is possible that these masses of long, parallel threads are the drifted remains of a Mastigograptus with exceedingly long, undivided, terminal branches; but as long as entire rhabdosomes have not been observed, a separation of the forms is the safer course.

Mastigograptus tenuiramosus (Walcott)

Plate 9, figures 2, 3; plate 10, figure 1; plate 11, figures 1–4; plate 12, figures 1, 2

Dendrograptus tenuiramosus Walcott. Utica Slate and Related Formations. 1879. p.21

Dendrograptus tenuiramosus Ulrich. Cat. Foss. Cincinnati Group. 1880.

Dendrograptus tenuiramosus Walcott. Alb. Inst. Trans. 1881. 10: 21; pl. 1, fig. 4

Dendrograptus tenuiramosus James. Cin. Soc. Nat. Hist. Man. Pal. Cincinnati Group, pt 2. 1892

Dendrograptus tenuiramosus Harper & Bassler. Cat. Foss. Trenton & Cincinnati Period. 1896. p.2

Dendrograptus tenuiramosus Gurley. Jour. Geol. 1896. 4: 300

Dendrograptus tenuiramosus Nickles. Cin. Soc. Nat. Hist. Jour. 1902. 20: 70

Description. Rhabdosome forming a densely branched bush attaining a size of 20+ cm; the branches extremely slender, especially in their long distal portions (.3 mm average width), given off monopodially and alternatingly at small, somewhat irregular intervals (1.5 mm at an average) and at an angle of 50°; this rather large angle giving the bushes a characteristic shrubby appearance in the central parts [*see* pl. 9, fig. 2], while the distal

parts are inclined to become pendent. The branches are filiform, smooth, as a rule retaining but a central row of circular pits (about 2.2 mm apart from each other), apparently only on one side of the branch. When perfectly preserved, rows of long conical pedunculate, obliquely ascending appendages, 1.2–1.5 mm long, are observed bearing on their pedunculate bases pairs of similarly shaped, usually shorter and slightly inward curved opposite cones.

Formation and localities. Walcott has recorded this species from the Utica slate, town of Trenton, Oneida co., N. Y. The New York State Museum possesses a large series of specimens from Holland Patent, town of Trenton, N. Y. which is the type locality. The fine specimens retaining the thecae here described and figured are in Dr Ulrich's collection and come from the lower third of the Eden shale at Covington, Ky. Another not very favorably preserved, very delicate specimen in the same collection, possibly belonging to another species is from the lower third of the Richmond group (Clarksville, O.). The occurrence of M. tenuiramosus in the Cincinnati group has long been recognized and the species cited from there by Ulrich [1880] as occurring between 0–200′ above low water, by James [1892] and Harper and Bassler [1896], the latter authors restricting its horizon to 50 to 200′ above low water mark. Nickles cites it in his *Geology of Cincinnati* from the "Lower Utica" (80 feet) only. Of its presence in the Lorraine shale of Canada I have been able to convince myself by a specimen from St Bruno mountain, County Chambly, Quebec, sent by Professor Whiteaves. Both the geographic distribution and the range of this species were hence quite considerable.

Fig. 114 Mastigograptus tenuiramosus (Walcott). Copies of original figures

Remarks. The novelty and probable significance for phylogenetic conclusions of the pedunculate theciform appendages of this species have already been noted in the discussion of the new genus here proposed.

It has also been observed at that place that the thicker branches at

least are probably composite in character and that in these thicker branches the pores are placed directly under the points of bifurcation, while in terminal undivided branches they appear in continuous series. The distances between them are, however, as a comparison of text figure 115 and plate 12, figure 1 will show, in both exactly equal, a fact which suggests that there is no essential difference in structure between the proximal and distal parts of the rhabdosome.

Walcott has already recognized the similarity of his species to M. (Psilophyton Lesq.) gracillimus (Lesq.) by pointing out their differences. M. tenuiramosus is said to have "smaller cellules and less robust stipe and branches," and Ulrich, the discoverer of the Cincinnati species, James, Harper and Bassler have all listed the two species separately, all of them referring Lesquereux's Psilophyton gracillimum to the graptolites, viz, to Dendrograptus.

Mastigograptus simplex (Walcott)

Plate 9, figure 1; plate 12, figures 3-5

Dendrograptus simplex Walcott. Utica Slate and Related Formations. 1879. p.20

Dendrograptus simplex Walcott. Alb. Inst. Trans. 1883. 10:20; pl. 1, fig. 5, 5a, 5b, 6

Dendrograptus simplex Walcott. Geol. Soc. Am. Bul. 1890. 1:347

Dendrograptus simplex ? Ami. Can. Rec. Sci. 1892. v. 5

Dendrograptus simplex Gurley. Jour. Geol. 1896. 4:300

Description. Rhabdosome of large size (large fragmentary rhabdosomes measure 20 cm and more in length), of fluitant appearance, the extremely slender, uniformly thick (about .1 mm–.45 mm) and very long branches being very flexuous in form and out of proportion thin to their length, suggesting the floating branches of aquatic plants.

The branching is monopodial or lateral, taking place at varying angles (60°–90°), alternating in distances of about 3 mm, but mostly appearing irregular and infrequent, probably through the loss of numerous secondary branches.

The branches bear circular or somewhat elongate pits, mostly halfway between the bifurcations or about 3 mm apart from each other; in the thinner terminal branches they approach to 2 mm.

Position and localities. This species is known to the writer from its original formation and locality, viz, the Utica slate of Holland Patent, Oneida co., N. Y. Walcott has also recorded it from Rome, N. Y. and Ami has identified it with doubt in collections from the Utica shale at Montreal and Shequenandad bay and islands.

Remarks. The characters of M. simplex, notably its thin, flexuous branches, are so striking that it is easily distinguished from its congeners. Whether this flexuosity is due to a lack of firmness of the branches, as it would appear at first glance, is doubtful, for numerous branches show, notwithstanding their small width, considerable substance and it is quite possible that their slenderness was coupled to considerable firmness, the irregular curving of the branches in that case resulting from their wiry character.

Fig. 115 Mastigograptus simplex (Walcott). Enlargement (x 7) of branch showing thecal apertures

As in M. tenuiramosus, a constant relation exists also in this form between the alternating branches and pits, and if one follows the central groove [*see* pl. 12, fig. 5] one discerns outlines of tubes proceeding into the branches or rather into short processes which apparently are the bases of the branches that have been stripped off before fossilization. If the latter is the case, the rhabdosomes bore considerably more branches, at least in the central parts, than would appear now, while the branches of the last order have indeed attained great length without further bifurcation.

Mastigograptus gracillimus (Lesquereux)

Plate 10, figure 2

Psilophyton gracillimus Lesq. Am. Phil. Soc. Proc. 1878. 17: 164; pl. 4, fig. 2

Dendrograptus (Psilophyton) gracillimus Walcott. Utica Slate and Related Formations. 1879. p.21

Dendrograptus (Psilophyton) gracillimus Walcott. Alb. Inst. Trans. 1883. 10: 21

Dendrograptus gracillimus Ulrich. Cat. Foss. Cincinnati Group O., Ind. and Ky. 1880

Dendrograptus gracillimum James. Cin. Soc. Nat. Hist. Jour. 1885. p.160; pl. 9, fig. 5

Dendrograptus gracillimus James. Cin. Soc. Nat. Hist. Jour. 1892. p.149

Dendrograptus gracillimus Harper & Bassler. Cat. Foss. Trenton and Cincinnati Periods in Vicinity of Cincinnati, O. 1896

Dendrograptus gracillimus Gurley. Jour. Geol. 1896. 4:95

Dendrograptus gracillimus Nickles. Cin. Soc. Nat. Hist. Jour. 1902. 20:68

Lesquereux considered this form as a Siluric land plant and described it as follows:

Stem very slender, dichotomously branching, smooth or naked half round, slightly channeled in the length; branches numerous, of various length, filiform.

The stem is scarcely 1 mm thick at the base; the upper branches curved as from a spiral unfolding, are slender, gradually attenuated and capilliform, or of the thickness of thin thread at their extremities.

Near Covington, opposite Cincinnati in the bed of the Licking river. Found by Mr Ed. Ulrich, communicated by Rev. H. Herzer.

Fig. 116–18 Mastigograptus gracillimus (Lesquereux). Fig. 116 Copy of original figure. Fig. 117, 118 Enlargements (x 5) of portions of branches

Dr Ulrich informs me that the type here referred to, has been loaned by him to Rev. Herzer and probably sold with the collection of the latter to Prof. J. Hall. In that case it is now in the possession of Chicago University which has lately acquired the remainder of Hall's collections and is at present not accessible. Dr Ulrich has, however, been kind enough to send me two specimens which he states are from the same locality and undoubtedly conspecific with Lesquereux's type (topotypes).

These have furnished us the following data:

A stem which has a diameter of .8+ mm is so little compressed that it

appears to have been very solid. Its surface is smooth and fails to show traces of growth lines. The branches which are given off monopodially have a thickness that is a little greater than that of tenuiramosus and are seen in one specimen to contract and expand regularly about eight times in 10 mm from 2 mm to 2.5 mm, producing an apparent jointed structure [*see* fig. 117, 118]. Whether these segments correspond to thecae or to the internodes between the bases of branches of the third order which are all broken off, is not distinctly shown by the material in hand but the fact of the abrupt, breaklike ending and that of the other specimen possessing narrower uniformly thick (.2 mm) branches point to the latter view as the correct one. In that case the branches of a higher order are here arranged a little closer than in M. tenuiramosus, but otherwise the two species are so similar that larger collections with more complete rhabdosomes — for all we have at present are obviously but fragments — may prove their specific identity.

Mastigograptus arundinaceus (Hall)

Plate 12, figure 6

Graptolithus arundinaceus Hall. Pal. N. Y. 1847. vol. 1, pl. 74, fig. 8, 8a

Dicranograptus arundinaceus Hall. N. Y. State Cab. Nat. Hist. 20th Rep't. 1868. p.227

Dendrograptus arundinaceus Gurley. Jour. Geol. 1896. 4 : 84

This species is based on a single fragment, which was figured by Hall, but not mentioned in either text or index and hence has been overlooked entirely by cataloguers. Gurley was then the first to publish a note on the specimen, stating that "Hall's figure gives as much information as would a description of the same specimen, which, of course, is a mere fragment" and adding, "I was able, however, to make out the distinction from it of the Dendrograpti subsequently published."

Fig. 119 Mastigograptus arundinaceus (Hall). Copies of original figures

In his manuscript we find the following description :

The type specimen shows little that can not be inferred from Hall's figure. The substance is a very thin film. Along the median line of both

stem and branches a very fine continuous ridge runs. The stem shows, at intervals of about 1.5 mm, cross furrows which may correspond to thecal apertures.

Horizon and locality. Utica slate, Turin, Lewis co., N. Y. (label on type specimen in Am. Mus. of Nat. Hist., New York city).

Through the kindness of Professor Whitfield the type specimen has been loaned to the present writer for study and a much enlarged camera drawing obtained [*see* pl. 12, fig. 6] which illustrates additional features. The branch shows the same median line as observed in M. tenuiramosus and M. simplex and distinct circular pits, from 2 mm–2.5 mm apart. The form is hence brought into association with the just mentioned species under Mastigograptus. While we believe with Gurley that it is different from these other species, its measurements (width of 4 mm and distance of pits) are very close to those of M. simplex and it is very closely related, at least, to that species, the fragmentary state of the type precluding any positive conclusion.

Mastigograptus circinalis sp. nov.

Plate 10, figure 3; plate 12, figures 7, 8

Dendrograptus sp. Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.528

Description. Rhabdosome small, consisting of very thin (.2 mm) filiform, extremely flexuous stem and equally flexuous, still thinner alternating branches dividing repeatedly into long branches of higher orders, the process of subdivision continuing until almost invisible, long hairlike branches result. Stems and branches possess a strong tendency to become, each independently, enrolled. Thecal apertures seen as fine circular pits numbering 9 to 11 in the space of 10 mm.

Position and localities. Observed only in the Utica shale at the Rural cemetery near Albany, in association with Glossograptus quadrimucronatus var. cornutus, G. (?) eucharis and Climacograptus putillus.

Remarks. In a paper on the Hudson River beds near Albany, the writer has cited this form as Dendrograptus sp., commenting on its points of similarity with Thamnograptus capillaris and M. ten-

uiramosus. The former is a Normanskill shale form that has the slender filiform character in common with this species but lacks the close branching, while M. tenuiramosus is distinctly coarser in its structure. The most striking characters of M. circinalis are to be seen in the extreme fineness and spiral and circinate involution of the branches. The latter seems to indicate a wiry nature which contrasts with their extreme slenderness and is not shown by the more flaccid Thamnograptus capillaris. It is possible that the small, curiously contorted tufts represent only the last, thin, terminal, drifted portions of a larger form; but however that may be, this form obviously possesses peculiar characters not shown by other species known at present.

GENERA INCERTAE SEDIS

CHAUNOGRAPTUS Hall

In the 11th Report of the State Geologist of Indiana (for 1881) Hall has proposed a subgenus Chaunograptus of Dendrograptus for a curious species of minute, glossy, black tubular bodies found mostly attached to valves. The species description serves as diagnosis of the genus. The differences of this species from others of Dendrograptus are stated in the following remarks:

> This species is more lax and diffuse than any form of Dendrograptus known, and therefore has been separated from the typical forms of the genus. It occurs free among other fossils, or attached to some fragmentary portion of other bodies. In its habit of growth it is quite distinct from any of the forms heretofore illustrated, and it is probable it belongs to a division of the Hydrozoa which has not been recognized in the Palaeozoic formations.

Until recently only the single Waldron species was known and this had not been taken notice of by graptolithologists. Dr Clarke has lately discovered a specimen of a congeneric form in the Devonic rocks of Dolbel's brook, Grand Grève, Gaspé, which he describes as C. gracilis [1907, p.291]. It is also attached to a brachiopod valve (Leptostrophia magnifica) and though a little coarser than the Waldron form, clearly possesses the same structure. A third, new form was collected by the

writer some years ago in the Utica shale of the Mohawk Valley, N. Y., also in but one specimen. This is here described as C. gemmatus.

Although the rhabdosome of C. novellus has superficially the appearance of branching tubes and except in its carbonaceous substance appears to have little in common with the graptolites, closer inspection leaves no doubt of the composition of these tubes of cells resembling thecae. We have here [pl. 11, fig. 5] reproduced some of the best preserved portions of the type specimen to bring out their composition of small curved cells and the thecal character of the numerous short branches. Hall had fully recognized this structure, when he stated that "the branches and branchlets are marked by numerous cellules which are usually indicated by the appearance of abrupt expansion and contraction of the branches." The original drawings, however, fail entirely to bring out this feature. The Devonic specimen, though not so well preserved, shows also distinctly this composition and Clarke describes it as consisting "of curved, commalike bottle-shaped cells or branch segments, which bud in such a fashion from the preceding that the branches become slightly zigzag-shaped."

The Utica shale specimen is also fragmentary but more distinct in the parts preserved than the other types. It shows a common canal formed by the bases of the cells or thecae and abruptly outward bending cell bodies.

The attached, creeping mode of existence of two of the species and the peculiar form of the cells are so different from what we are accustomed to see in graptolites that one shrinks from definitely assigning the genus to that class. The question of the graptolitic nature of these forms was mooted in this office when Dr Clarke investigated the Devonic species and the possibility of its bryozoan nature considered. To attain clearness on the latter point the specimens were sent to Dr Ulrich who however has been unable to recognize them as bryozoans. They thus fall back into their old association and it becomes necessary to attempt to reconcile their anomalies with the normal graptolite structure.

The creeping mode while the prevailing one is apparently not their only one, for Hall states that C. novellus also occurs free and the type

of C. gemmatus has apparently been also free. Since the Dendroidea to which the genus if graptolitic, must belong, were mostly sessile, it would not imply a far-reaching change if some of these forms with weak branches would become creeping. To the form of the thecae approximation could be found in some of the other Dendroidea. Thus Dictyonema tuberosum Wiman and Dendrograptus? bottnicus Wiman [1895, pl. 12, fig. 12, 14] possess thecae which curve similarly abruptly and strongly outward with their distal portions, but are not almost entirely free as those of Chaunograptus. The latter feature, however, is seen in forms of Acanthograptus (as A. suecicus). The extremely small overlap of the thecae and their strong basal contraction may well be the cause of the weakness of the branches and the resulting adoption of a creeping mode of existence; thus that all these anomalies represent really but one.

Their path of development can be traced to some extent if we compare the oldest of the three species (C. gemmatus) with the later Siluric and Devonic forms. The first could be referred with almost equal propriety to Inocaulis of which genus it would be a slender representative. The stem [*see* text fig. 120] especially has a distinct Inocaulis-structure and the branches are more regularly alternating than in the later Chaunograpti. In C. novellus the branching is still obscurely alternating and in the Devonic form it is probably entirely irregular. The first was apparently still entirely free, for it possesses a stronger stem, while the last two species have equally thin stems and branches and probably normally sought support on foreign bodies. In both the latter species the branches and stem have become entirely lax and the thecae are irregularly bent forward and backward as opportunity of attachment on the substratum was offered.

A sicula has not been observed in any of the species.

Chaunograptus novellus Hall

Plate 10, figure 10; plate 11, figure 5

Dendrograptus (s. g. Chaunograptus) novellus Hall. Alb. Inst. Trans. v. 10. Abstract, p.2. 1879

Dendrograptus (Chaunograptus) novellus Hall. Geol. Sur. Ind. 11th Rep't. 1882. pl. 1, fig. 1, 2

Hall's description of this form is :

Fossil occurring free in the shales, or upon other fossil bodies, in slender branching fronds. Branches diverging, lax and slender, with numerous branchlets, both marked by numerous cellules which are usually indicated by the appearance of abrupt expansion and contraction of the branches.

The angular projection of the cell apertures can be observed in many parts of the fossil.

The only specimen (holotype) known to me is, according to the locality ticket, from the Waldron shale at Waldron, Shelby co., Ind. It consists of a valve of Spirifer radiatus that is covered with the thin (.1 mm), irregularly flexuous, glossy black tubes. The latter are as the camera enlargements here given show, composed of relatively long tubular thecae, which are frequently curved and often project with their distal, irregularly bent parts at varying angles from the axis of the branch. They overlap about one half their length and number about 21 in 10 mm. The width of the branches is but .15 mm–.2 mm and a continuous rhabdosome has a length of 23 mm. The walls of the thecae are relatively very thick and their outer aspect is rough and knotty and in some parts appears to be somewhat coarsely annulated.

Chaunograptus gemmatus sp. nov.

Plate 10, figure 11; plate 11, figures 6, 7

Description. Rhabdosome small, width of fragment about 11 mm; length but 5 mm; consisting of stem (.6 mm wide) and alternating, gently curved, slightly upward bending branches. Thecae tubular or elongate bottle-shaped with expanded apertures, growing with proximal two thirds of length in direction of branch and diverging at right angles with distal third, overlapping about one fourth, numbering about 28 in 10 mm.

Position and locality. The type specimen was collected by the writer in the Utica shale near Dolgeville, Herkimer co., N. Y.

A small fragment probably referable to this species has also been found in the Ulrich collection. It comes from the lower third of the Eden shale at Covington, Ky. [pl. 11, fig. 6, 7].

Remarks. The relations of this species to Inocaulis have been shown in the discussion of the genus. On account of its very fragmentary condition the specimen leaves many points unsettled; especially is the composition of the branches still shrouded in doubt; the stem is apparently composed of a dense mass of thecae opening on all sides, but it also shows a thin threadlike axis [*see* text fig. 120]. The coenosarcal canal of the branches seems to be composed of the narrow, tubular proximal parts of the thecae.

Fig. 120 Chaunograptus gemmatus sp. nov. Enlargement (x 5) of type specimen

The fragment in the Ulrich collection is very distinct, the specimen being jet-black in a light grayish green shale. In this specimen it appears that the thecae were fairly regularly alternating on opposite sides and lying in one plane. Where the branch is compressed in the direction of that plane, a black, nearly uniformly thick band results [*see* pl. 11, fig. 6, 7].

Chaunograptus ? rectilinea sp. nov.

Plate 10, figure 12

Description. Rhabdosome small (20 mm–30+ mm), repent on foreign bodies, consisting of very fine, nearly uniformly thick (.1 mm–.2 mm), straight or but gently curved, frequently and irregularly, monopodially dividing branches, the latter all forming acute angles (about 30°). There are no projecting thecae or denticles seen and the thecal apertures appear as fine circular depressions, numbering about 20 in 10 mm.

Position and locality. The material consists of a single fragment of an apparently undescribed cephalopod, that is covered with the linear carbonaceous rhabdosomes. It was found by the writer in the Utica shale at the north end of Van Schaick island, Cohoes, N. Y.

Remarks. The carbonaceous substance, the presence of small pores and the general graptolitic aspect of the organism which is that of a dendroid, similar to Mastigograptus seem to warrant the description of the form in this volume notwithstanding its repent mode of existence. The

latter it has in common with the species of Chaunograptus here also described. There is a strong possibility that it belongs to another class of the animal kingdom and its similarity to certain bryozoans such as e. g. Vinella might suggest its bryozoan affinities. Still we are not aware of any genus of fossil bryozoans with which it actually could be united. The reference to Chaunograptus is wholly tentative and based on the creeping, attached mode of existence and irregular branching. While Chaunograptus shows a clear composition of the branches of distinct thecae, they appear in this form as continuous tubes; but it must be conceded that the branches are too thin and the preservation is not quite good enough to permit a conclusive observation in regard to this and other points. It is e. g. quite possible or even probable that the numerous short branches, seen in C. ? rectilinea in uniserial succession, correspond to the short projecting thecae of C. novellus which also appear as short branches. Their approximately uniform length and slight widening in distal direction are quite suggestive of such an explanation. On the other hand, from its general aspect alone one would feel inclined to bring this species under Mastigograptus as we have noted before and the appearance of the apertures as simple pores would support this reference.

Fig. 121 Chaunograptus ? rectilinea sp. nov. Enlargement (x 7) of portion of type

CORYNOIDES Nicholson. 1867

As the original description of the genus has to be regarded that of the genotype, C. calicularis, which concludes with the following short diagnosis: "Corynoides forms a hollow tube, probably corneous, provided with a single or double radicle or mucro, and developed distally into a cuplike 'hydrotheca.' Unlike the Graptolitidae proper, Corynoides has evidently been composed of a single polypite only, though it resembles the typical Graptolites, in having been apparently free and oceanic, and in the possession of a corneous or subcalcareous test or polypary."

Under the impression that the organism could have only consisted of a single polypite, Nicholson considered it as analogous to the Corynidae, regarding it as "especially resembling such forms as Corymorpha, in which there is but a single polypite," and named the genus accordingly, but refraining from an absolute reference to the Corynidae because Corynoides in his opinion existed as "an independent or free-floating organism."[1]

This diagnosis of Corynoides has been maintained by Nicholson in his *Monograph of the British Graptolites*, and in 1874 [Quar. Jour. 1875, 31 :633] Hopkinson and Lapworth made the genus the representative of a separate family Corynograptidae and of a section (Corynoidea) of the Rhabdophora, giving it equal rank with the Graptoloidea and Retioloidea; and at the same time changing the name into Corynograptus for the sake of uniformity. Lapworth did not, in later publications, maintain this new name to which the same criticisms and arguments apply that have been made in regard to the changing of Dictyonema into Dictyograptus, proposed at the same time and place.

Fig. 122 Corynoides calicularis Nicholson. Copies of original figures

A second species, C. gracilis, was described in 1872 by Hopkinson. His conception of this species was that it probably consisted of but one theca with about five terminal teeth, which are the terminations of fibres that may have supported the less rigid and more membranous portion of the polypary, as the frame of an umbrella supports its cover.

Lapworth figured in 1876 in the *Catalogue of the Western Scottish Fossils* a third species, C. curtus which was described in the following year.

In Nicholson and Lydekker's *Manual of Palaeontology* we find Corynoides again noticed as "a singular genus, which differs from all the ordi-

[1] A Diplograptus of the subgenus Cephalograptus, D. tubulariformis is described by the same author as apparently constituting a transition form between Corynoides and the true Graptolites.

nary Graptolites." It is described as consisting "of a cylindrical chitinous tube, tapering towards the base, where it is furnished with two small spines, and expanding above into a species of toothed cup." This conception is illustrated by the appended figures [*see* text fig. 123] copied from the Manual.

Frech had obviously to base his conception of the genus upon such figures only as were extant at the time, and guided mainly by Hopkinson's figure of C. gracilis, he has stated that Corynoides is clearly a Cephalograptus of spoonlike outline, with six thecae, the apertures of which lie in one row at the "proximal" end. He would, therefore, by the strict law of priority replace the term Cephalograptus by Corynoides if, in his opinion, the description of the latter genus was not based upon insufficient material.

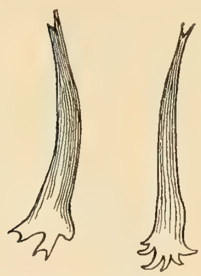

Fig. 123 Corynoides calicularis Nicholson. Copies of Nicholson's figures in the *Manual of Palaeontology*

Dr Gurley had, according to his manuscript notes, recognized but one species, viz, C. calicularis in his collection from Stockport, Columbia co., N. Y. and this had left him in doubt as to the structure of the rhabdosome, especially as to the question, whether it consisted of one or several thecae. He states:

This species possesses either two or three hydrothecae or it consists of a single hydrothecal tube with several mouths. The latter supposition seems to be the one indicated by Professor Nicholson's figure in *Monograph of the British Graptolites* [p.132, fig. 74]. The former, however, seemed to me more probable from the appearance of the American specimens. He adds: "However, it may be concerning the simple or multiple thecate character of Corynoides it is certain that the structure of the genus is more complex than has heretofore been supposed. Thus one specimen was seen where two of these tubes originate from a common stem. Several other more doubtful specimens were seen. One of these showed two branches with a common origin which simulated closely a sicula."

In the manuscript for a bulletin on the Dendroidea by the same author, C. calicularis is arranged with this latter class of graptolites. No explanation for this arrangement is given, but I presume that the last cited observation has led to this conclusion on the taxonomic position of the genus. The accompanying text figures were found with the manuscript.

In America the genus has been first noted by Hall, who repeatedly has figured typical Corynoides as "germs"; thus in *Palaeontology of New York*, volume 3, page 508, figure 7, where the form, here described as C. calicularis, is readily recognized in the woodcut. It is explained as "apparently the young of one of the singly serrated forms." Another very correctly drawn example [1865, pl. B, fig. 19, *see* text fig. 125] which distinctly shows the basal part as described in this paper, is designated as "a germ where the solid axis is on one side; the species probably belongs to the monoprionidian type." C. calicularis has been recognized in the Normanskill shale of Canada and New York by Nicholson, Lapworth and Gurley. The occurrence of a species in the Utica shale was later announced by the present writer [1900].

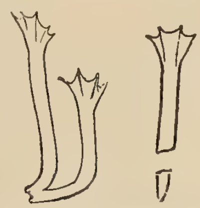

Fig. 124 Corynoides calicularis Nicholson. Copies of Gurley's manuscript figures

Comparing the figures of Corynoides hitherto published with my material, which comprises at least three different species, and an abundance of excellently preserved specimens, I find that Whitfield's early figure of the germ from the Normanskill shale had for its basis evidently a more complete specimen than the English authors had access to, for it shows not only a nema but also the small transverse basal part, which I consider as the sicula. It has been necessary to reproduce a considerable number of specimens in enlarged drawings to bring out the details of their structure and to illustrate their various aspects [*see* text fig. 126 *et seq.* and pl. 13].

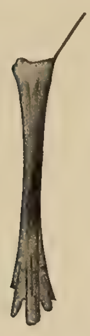

Fig. 125 Corynoides calicularis Nicholson. Copy of Hall's figure of a "germ" in Can. Org. Remains

The structure of the rhabdosome of Corynoides which my material leads me to infer is that of a sicula bearing three thecae in the mature rhabdosome. The sicula does not seem to differ in form or character from that of other graptolite genera. It is a rather short, somewhat rapidly expanding cone, suspended from a nema, which sometimes attains considerable length. Its aperture is plain, without appendages or spines. The thecae originate close together by successive budding and remain united throughout their entire growth. The oldest

theca is found nearest to the apical part of the sicula and buds very close to the apex of the latter. The second theca buds, as far as my material shows, from the first theca and close to its budding point and the third from the second also close to the apex of the latter. As a result of the proximity of these points of origin, all three thecae seem to spring from the sicula, and the latter is more or less forced out of its original direction, a feature which is most developed in C. calicularis on account of the relative stoutness and width of the thecae [*see* text fig. 126–31]. In the long and slender C. gracilis, the sicula and thecae retain nearly the same direction.

From the fact that in C. calicularis which lends itself best to a study of the structure, one observes two thecae, when the rhabdosome is seen from one side, and three when it is seen from the other [*see* text fig. 126, 127, 129, 130], I infer that the second and third thecae arranged themselves symmetrically on both sides and a little forward of the first thecae, thus that the second came to lie on the right and the third on the left side of the sicula. In specimens, like that reproduced in figure 129, where one part of the rhabdosome is preserved with the periderm and the other only in a cast of the latter, this relative position of the three thecae becomes directly visible [*see also* fig. 127].

It is possible that the rhabdosomes of this genus were united into a colony of still higher order. At least would this seem to be suggested by occurrences like that reproduced in plate 13, figure 17, where a number of rhabdosomes form a group which on account of the direction of the rhabdosomes and the fact that no other specimens of Corynoides were found on the same slab — which is quite barren of fossils — quite likely represents an original condition. Also another group is quite suggestive, though on account of the great number of individuals on the slab more liable to be the result of accidental drifting. Whether the peculiar appendages of the nema, which in text figure 131 have the shape of small triangles and therefore might well be the apical parts of siculae, indicate a further composition of the colonies, is very doubtful, since similar appendages of the nema have also been observed in other genera.

The most striking feature of at least two of the species of Corynoides observed in our rocks are the apertural appendages which, resembling symbolized flames, cap the bundle of thecae. They consist of several pairs of diverging curved spines (presumably one pair for each theca) which project from tonguelike processes of the thecae.

In case it should be proven that the rhabdosome indeed formed compound colonies, the latter would be synrhabdosomes, such as the colonies of Diplograptus are, where each component rhabdosome begins to grow from its own sicula; and not comparable to the branching colonies of the Dichograptidae. Corynoides could then appear to be an aberrant type of the Axonophora. There is, however, no trace of an axis or virgula in either the sicula or the outgrowing branches seen nor would there seem to be any need for a strengthening rod in the short compact rhabdosome.

If, on the other hand, the rhabdosome represent the whole colony, if there is no axis and the thecae bud in single series and succession, this form could be compared to Azygograptus and considered as a peculiar late development of the Didymograpti. Such view would, however, be contradicted by the peculiar character of the thecae and especially that of the apertural appendages which seem to suggest a more complex structure of the thecae than is found in the Dichograptidae. We consider it, for this reason, possible that the genus may be found to represent an aberrant branch of the Dendroidea and leave it, for the present, among the *formae incertae sedis.*

Whatever the derivation of this remarkable group of minute forms may have been, it stands so distinctly apart in the shape and structure in which it presents itself to us, that we fully agree with Hopkinson and Lapworth in separating it from the rest of the Graptoloidea and placing it in a separate family, which since the name Corynograptus has again been abandoned, would have to receive the name Corynoideae instead of Corynograptidae.

Our rocks have furnished five forms, all of which are easily distinguished by the relative width and length of their rhabdosomes. Since

these characters spring most distinctly into the eyes, when whole groups are observed, I have reproduced such in natural size as they were found upon the slabs. The forms are:

Corynoides calicularis *Nicholson*
C. gracilis *Hopkinson*
mut. perungulatus *nov.*
C. curtus *Lapworth*
var. comma *nov.*

Of these C. calicularis is restricted to the Normanskill shale; C. gracilis is very common in the same beds in a mutation (perungulatus) and found in association with C. calicularis. The typical form is somewhat younger and persists into the Lorraine beds, but is absent in the Utica shale. C. curtus is a Utica form and the var. comma has been observed only in the lowest Utica horizon at Mechanicville, where it is, however, a common form. C. calicularis and C. curtus var. comma did not pass out of the Appalachian basin, except to the east, where the former occurs in Canada and Great Britain. C. gracilis and C. curtus, however, were carried beyond the western barrier into the Mississippi basin and have been found in the Mohawk valley and Arkansas.

The genus appears in the Normanskill shale and dies out again at the end of Lorraine time. Its range does not seem to be greater in Europe.

Corynoides calicularis Nicholson

Plate 13, figures 1, 6–8

Graptolite germs Hall. Pal. N. Y. 1859. 3: 508, fig. 7

Graptolite germs Hall. Can. Org. Rem. Dec. 2, 1865. pl. B, fig. 19

Corynoides calicularis Nicholson. Geol. Mag. 1867. 4: 108; pl. 7, fig. 9–11

Corynoides calicularis Hopkinson. Geol. Mag. 1872. 9: 502

Corynoides calicularis Nicholson. Monogr. Brit. Grapt. 1872. p.132, figure

? Corynoides calicularis Nicholson. Ann. & Mag. Nat. Hist. 1873. 11: 143

Corynoides calicularis Lapworth. Cat. West. Scottish Foss. 1876. p.7; pl. 4, fig. 91

Corynoides calycularis Lapworth. Belfast Nat. Field Club Rep't & Proc. v. 1, pt 4 apx. 1877. pl. 7, fig. 18

Corynoides calycularis Linnarsson. Sveriges Geol. Unders. Ser. C, no. 31. 1879. p.18

Corynoides calycularis Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4: 177

Corynoides calicularis Nicholson & Lydekker. Man. of Pal. 1889. p.215, fig. 96

Corynoides calicularis Gurley. Jour. Geol. 1896. 4: 94, 301

Corynoides calicularis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.515 et seq.

Corynoides calicularis Clark. Geol. Mag. Ser. 4, v. 9. 1902. p.498

Corynoides calicularis Weller. Geol. Sur. N. J. Pal. 1903. 3: 52

Description. Rhabdosome short (6–8 mm) and relatively broad (about 1 mm), of uniform width, consisting of a sicula and three thecae. Sicula small (2 mm), conical, without apertural processes, in mature specimens

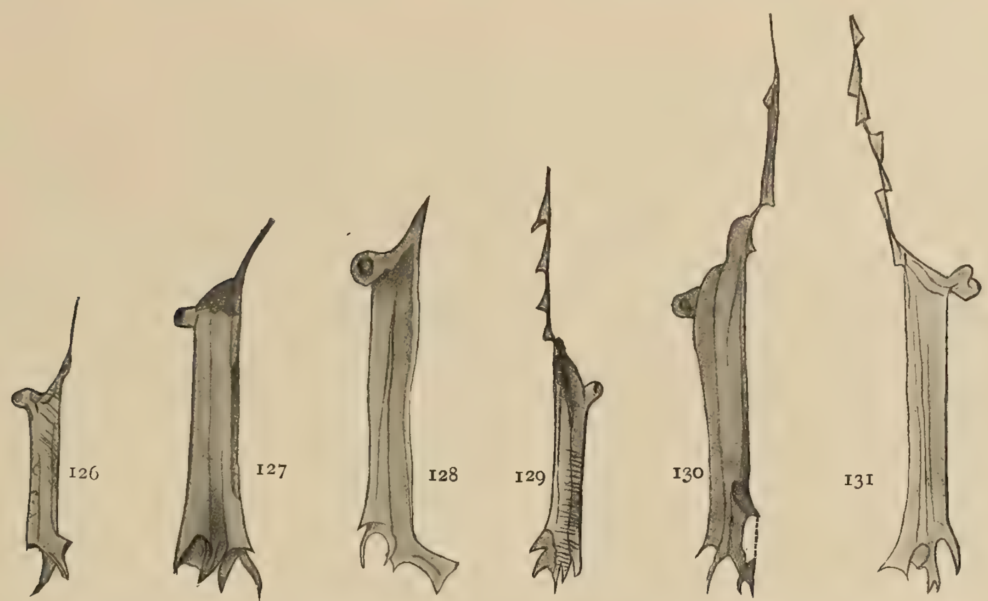

Fig. 126–31 Corynoides calicularis Nicholson. Enlargements (x 7) of rhabdosomes from the Normanskill shale at Glenmont, N. Y.

slightly recurving, suspended from a long and slender nema. Thecae slender tubes of uniform width, all originating close to the sicula, arranged in a bundle which forms an angle of 50° with the sicula. Apertures straight, normal to the axes of the thecae, all adjoining at the distal extremity of the rhabdosome, each provided with a pair of usually curved strong spines, which often appear to be raised upon a tonguelike process. Nema thin and filiform.

Position and localities. This species is common and beautifully preserved in the collections from the Normanskill shales in the cut of the West Shore Railroad near Glenmont, south of Albany. It is also found in numerous other localities in the slate belt of New York, where the Normanskill zone is exposed and has been reported by the writer [1901] from a number of these in the neighborhoods of Albany, Troy and Castleton. It is further recorded in Dr Gurley's manuscript from Stockport, Columbia co., N. Y., upon identification by Lapworth and has been reported from Canada.

The type material of the species was found in the "more anthracitic shales" of Dobb's Linn, and of Hartfell near Moffat, Scotland and Lapworth cites it as occurring in the Hartfell and Moffat shales.

It is also mentioned by Linnarsson as occurring in Scania in association with Glossogr. quadrimucronatus, Diplogr. foliaceus, Climacogr. bicornis and other forms.

Remarks. The original description of this species is:

The stipe varies in length from 1/3 to 1/2 inch, and has an average breadth of 1/20 inch; the base, or proximal extremity, is provided with two small, slightly diverging spines or mucros which are wanting in other less perfect specimens, when the stipe terminates below by tapering to a point. There are no cellules, the lateral margins of the stipe being perfectly plain; but the polypary expands at its distal extremity into a sort of cup or calyx, the free edge of which is divided into four or five equal or unequal teeth. There are no certain traces of any central solid axis, but the surface of the stipe is sometimes striated.

It will be seen, that our form agrees fully with this accurate description, and that the Scottish specimens are somewhat larger than the average of ours, though our extreme specimens approach the maximal measurements of the Scottish types.

Nicholson figured and described this species as possessing two diverging spines or mucros when perfect [*see* text fig. 123]. It appears from our material that one of these mucros is the apical point of the sicula, the other its aperture. The misconception may easily have arisen from the peculiar fact that in this species the sicula, apparently under the weight of the

bundle of thecae, suspended from it, becomes more or less bent upon itself [*see* text fig. 126].

C. calicularis is at once distinguished from all of its congeners in the rocks of New York by its short and at the same time stout habit, and the prominent curved apertural spines. It shows a longer nema than any of the other species have exhibited and this is frequently curved directly above the sicula, evidently because the latter has been forced out of its original vertical position in the suspended rhabdosome by the weight of the heavier bundle of thecae which naturally assumed the vertical position itself.

Fig. 132 Corynoides calicularis Nicholson. Copy of Lapworth's figure in Proc. Belfast Nat. Field Club

The nema attained a length of two or three times that of the rhabdosome. It is in this species that the peculiar appendages of the nema, mentioned before, are observed most frequently [*see* also text fig. 29, 30].

The aperture of the sicula was distinctly circular and devoid of all appendages. The apertural part, projecting beyond the bases of the thecae, presents sometimes a wrinkled or withered appearance, as if it had fallen into disuse during the lifetime of the colony.

Corynoides gracilis Hopkinson

Plate 13, figures 2, 12, 15, 16

Corynoides gracilis Hopkinson. Geol. Mag. 1872. 9: 502; pl. 12, fig. 1

Corynoides gracilis Lapworth. Cat. West. Scottish Foss. 1876. p.7; pl. 4, fig. 93

Description. Rhabdosome long (12 mm) and narrow (.4–.5 mm), slightly curved, of uniform width, composed of a sicula and three thecae. Sicula long (.2 mm) and narrow. Thecae extremely slender, of uniform width, not divergent from the sicula, bent outward near their aperture; each provided with two short straight mucros. Apertures of thecae straight, perpendicular to the axis of the theca. Nema thin and filiform.

Position and localities. This, the typical form of C. gracilis, has been observed by me only in beds which I consider as somewhat younger than the typical Normanskill zone [*see* p. 18] viz, at the power house

at Lansingburg, in immense numbers and in association with Dipl. amplexicaulis var. pertenuis and Climacogr. modestus; in Rusher's quarry in south Troy in association with Dipl. amplexicaulis; and at Bakers Falls (Sandy Hill, Washington co.), in association with Diplogr. amplexicaulis and Trocholites ammonius.

C. gracilis is recorded by Lapworth only from the Hartfell shales of Scotland.

Remarks. The original description of C. gracilis reads:

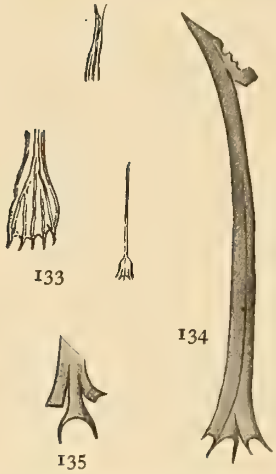

Fig. 133-35 Corynoides gracilis Hopkinson. Fig. 133 Copies of Hopkinson's original figures. Fig. 134 A specimen which shows the sicula and the diverging apertures of the three thecae. Fig. 135 Distal extremity of another rhabdosome. The last two figures are enlarged x 7

> Polypary from about 5/8 to 3/4 inch in length, and about 1/50 of an inch in average breadth, gradually expanding from the proximal to the distal end, where there is a slight bulbous expansion terminating in short acutely pointed teeth.
>
> Commencing with two slender radicular processes which lie so close together that they are scarcely individually perceptible, the polypary, here not 1/100 of an inch in breadth, gradually enlarges until a breadth of nearly 1/30 of an inch is attained. Up to this point the margins of the polypary are almost perfectly straight, but here there is a slight enlargement, which in C. calicularis (Nich.), has been described as a "cuplike hydrotheca." This portion of the polypary is about 1/20 of an inch in length, and scarcely 1/20 in breadth at its widest part. It is convex in form, and terminates distally in about five acutely pointed teeth, which at first sight appear to form the greater part of this so called hydrotheca. But this appearance is caused by several fibers, somewhat resembling the virgula of the typical graptolites, which traverse the polypary throughout its length, and form the extreme distal termination of each of these segments, which are really connected together to within a short distance of their apices. These fibers, whatever their nature may be, apparently form a framework which supports the less rigid and more membranous portion of the polypary, as the frame of an umbrella supports its cover.

As in C. calicularis, also here our specimens fail to attain the maximal length of the Scottish type, but fully agree in the other dimensions given. Our material tallies exactly with the figure given by Lapworth in the *Catalogue of the Western Scottish Fossils.* The fibers mentioned in

Hopkinson's elaborate description as traversing the rhabdosome throughout its length, are the partition walls between the thecal cavities compressed or projected into one plane.

The "bulbous expansion" is caused by the abrupt divergence of the last portions of the thecae.

The slender form and the divergence of the thecae near the aperture are characters which readily distinguish this form from its congeners.

Corynoides gracilis Hopkinson mut. **perungulatus** nov.

Plate 13, figures 3, 9, 10, 11, 13, 14

Description. Rhabdosome relatively long (10–12 mm), narrow (.5–.85 mm), straight, of uniform width and rigid appearance, consisting of a sicula and three thecae. Sicula long (2.4 mm) and thin, with circular and unprotected aperture. Thecae very slender, hardly widening in apertural direction, not divergent from the sicula. Aperture straight, normal to the axis of the theca. Distal extremity of the mature rhabdosome furnished with three clawlike spines which project upon a tonguelike process. Nema very thin and filiform.

136 137 138 139

Fig. 136-39 Corynoides gracilis mut. perungulatus nov. Fig. 136, 137 Specimens showing the sicula and apertural spines. Fig. 138 Fragmentary specimen showing the oldest theca. Fig. 139 Sicula. The originals from the Normanskill shale at Glenmont and enlarged x 7

Position and localities. This mutation is a very abundant form in the Normanskill shales (Dicellograptus zone) at Glenmont, Albany co., but has also been observed in a few other localities, in the same horizon, as at Mount Moreno near Hudson and Speigletown, north of Troy. It also seems to occur in homotaxial beds in Arkansas.

Remarks. From the other species of Corynoides this one is easily distinguished by its slender, straight form. Its most striking feature is the

apertural process which in its best development would seem to suggest that it may have served still another function than that of protecting the apertures and have been the bearer of some separate organ or specialized individual. This process and the absence of the spreading of the theca near the aperture, observed in the typical form, are the principal characters distinctive from the latter. The two have not been found in association, but are bound to different localities and faunules.

Corynoides curtus Lapworth

Plate 13, figures 4, 17–21

Corynoides curtus Lapworth. Cat. West. Scottish Foss. 1876. p.7; pl. 4, fig. 92

Corynoides curtus Lapworth. Belfast Nat. Field Club. Rep't & Proc. v. 1, pt 4. Apx. 1877. pl. 7, fig. 19

Corynoides curtus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.514ff.

Description. Rhabdosome small (6–7 mm, in the great majority 6 mm), narrow (.4–.5 mm), curved, consisting of a sicula and three thecae. Sicula inconspicuous (in the average 1 mm long); short and broad, without apertural spines. Thecae long and extremely narrow; of uniform width, not diverging from the sicula; provided with one apertural spine each, which is situated on the inner or upper margin of the theca and projects obliquely outward. Apertural margin straight, normal to the axis of the theca. Nema thin and flexuous.

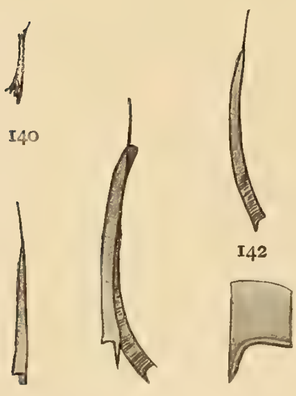

Fig. 140–44 Corynoides curtus Lapworth. Fig. 140 Copy of original figure. Fig. 141, 142 Young specimens. Fig. 143 Mature specimen. Fig. 144 Aperture of the longer theca of the same. Figures 141–44, x 7

Position and localities. The writer has cited this form in a former publication from the Utica shale at the Rural cemetery in Albany,— where it is found beautifully preserved in association with Glossogr. quadrimucronatus var. cornutus, Climacogr. putillus, G. (?) eucharis and Utica shale brachiopods,— at the penitentiary in Albany, at Ward's lane, north of Albany, and the Normanskill near Albany. There are in the State Museum slabs of Utica shale from

the neighborhood of Amsterdam in the Mohawk valley, that are covered with this form in surprising multitudes and to the exclusion of all other fossils. It was further found by the writer in the transition beds from the Trenton limestone to the Utica shale along the shore at Panton, Vt.; and also observed on the east shore of Green Island, opposite the city of Troy, in association with Dipl. foliaceus, Clim. typicalis and a mollusk fauna which indicates the highest horizon of the Utica shale or an approach to the Lorraine beds. The form cited in the above mentioned publication as C. curtus and as occurring at Mechanicville in association with Climacogr. caudatus, etc. has here been made the type of a separate variety (C. curtus var. comma).

C. curtus can be said to range in New York throughout the whole Utica formation and to be characteristic of the same. A peculiarity of its distribution in this formation is that, while it is a regular constituent of the Utica shale fauna in the Hudson valley and still very common in the lower Mohawk valley (Amsterdam, Sprakers Basin), it has not been observed at all by the writer in the well searched Utica beds of the middle and upper Mohawk valley and west of the Adirondacks.

Lapworth records this species from the Hartfell shales in S. Scotland and from County Down in Ireland.

Remarks. The small size and graceful curvature of the rhabdosome distinguish this form from others with the exception of the variety described below, which is still shorter, more compact in appearance and more strongly curved. The armature of the aperture is much reduced when compared with the earlier forms, and altogether this form appears more primitive than its predecessors. The sicula is missing in the great majority of the specimens and seems to have been easily lost or been so thin, that it frequently failed to be preserved in the rock.

The thecae seem to have all originated in close proximity to the sicula, but the first theca attained considerable size before the second and third began to bud, for in numerous apparently unmutilated specimens only the sicula and one, nearly full grown theca are observable. The same observation has been made in regard to C. gracilis.

Corynoides curtus Lapworth var. **comma** nov.

Plate 13, figures 5, 22–24

Corynoides curtus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p. 526

Description. Rhabdosome very small (average 4 mm, maximal length 5 mm) and relatively wide (.6 mm), attaining its maximal width at half its length, strongly curved so as to frequently describe a quadrant, consisting of a small, inconspicuous sicula (.6 mm), which rarely is preserved, and three thecae. Thecae not diverging from the sicula; of equal length. Aperture of the sicula plain, those of the thecae straight, normal to the axes of the thecae and provided with one mucro each, that is of the same character and direction as in the typical species. Nema present.

Fig. 145–48 Corynoides curtus var. comma nov. Fig. 115–47 Common aspect of the form. Fig. 148 A larger specimen. x 7

Position and locality. Very common in the shales, exposed at the power house below Mechanicville. It is there associated with Glossogr. quadrimucronatus, Diplogr. foliaceus, Climacogr. caudatus, and numerous mollusks indicating a horizon transitional between the Trenton and Utica formations or lying near the base of the Utica formation.

Remarks. In the above cited publication this form has been referred to C. curtus, but the constancy of its differential characters requires its recognition as a separate variety (or mutation). It differs from the typical curtus by its shorter and at the same time stouter form and its marked curvature, while the diminutive size of the sicula, the curvature and especially the obliquely outward direction of the apertural spines clearly indicate so close a relationship to C. curtus that the ends of taxonomy appear to be served best by retaining this form within the bounds of the typical Utica species of Corynoides.

Protovirgularia dichotoma (McCoy) ? Gurley

Plate 10, figure 9; plate 11, figures 8, 9

Protovirgularia dichotoma McCoy. Ann. & Mag. Nat. Hist. 1850. 6: 272, 273

Protovirgularia dichotoma McCoy. Brit. Ass'n 20th Rep't. Notices and Abstract. 1851. p.107

Protovirgularia dichotoma McCoy. In Brit. Pal. Foss. (Sedgwick Brit. Pal. Rocks). 1853. p.10; pl. 1B, fig. 11, 11a, 12, 12a

Protovirgularia dichotoma Malaise. Acad. Roy. Belg. Bul. 1890. 20: 447

The collection of graptolites from the Normanskill shale at Stockport, Columbia co., N. Y. in the National Museum, contains two curious small fossils which are obviously graptolites but differ in structure from all associated forms. They have been identified by Dr Gurley with Protovirgularia dichotoma and the following description is given in his manuscript:

Fig. 149 Protovirgularia dichotoma (McCoy)? Gurley. Pen drawing of one of the Stockport specimens made under Dr Gurley's supervision. x 2

Of this species, which appears not to have been observed since McCoy's time, I have two specimens, one not very well preserved, showing two branches of the polypary and the other a short fragment of a branch in a fair degree of preservation. Neither of these show any details, such as McCoy describes and figures. All that can be said from them is that the branches are about 1.5 mm wide and the transverse spiculate processes about 32 in 25 mm. The last feature contrasts with McCoy's description, which gives the number as 24 in 25 mm. Besides these definite points of structure, both specimens are surrounded in the rock by some indefinite lines and a general filmy appearance somewhat resembling that occurring in the scopulate specimens of Diplograptus pristis (?). I suspect that the present species possesses more structure than is now known and that perhaps the polypary described by McCoy may prove only the framework (of a more resistant substance) than the rest of the individual.

Horizon and locality. Two specimens from the Lower *Dicellograpsus* zone, Stockport, N. Y.

The text figure 149 was made under the supervision of Dr Gurley. We add two camera enlargements which were obtained with the aid of a strong illuminating lens when the specimens were immersed. From these latter figures one gets the impression that the transverse spiculate processes

were but the stronger bases of saclike appendages, which in some places are quite distinct. One [pl. 11, fig. 8] would seem to have an aperture. The transverse bars proceed from the stems first obliquely upward and then horizontally outward. Near the base of one specimen they can be traced farther down along the stem and have the appearance of long narrow tubes.

If McCoy's description and figures of his Protovirgularia dichotoma are correct, and the lateral branches or "pinnules" are "transversely ridged with about five parallel cylindrical cells placed at right angles to its length," then the similarity of our and the British form would seem to be but superficial. At any rate the stems and bases of the secondary branches have the aspect of a Thamnograptus and since one of the two specimens is also involved in a bundle of rhabdosomes of Thamnograptus typus, it is, in my opinion, possible and even probable that these fossils which appear so abnormal are but a part of the rhabdosome of T. typus which has already been demonstrated in this paper to combine three former species of Thamnograptus, so different are the aspects of its various parts. The "Protovirgularia" from Stockport may be a branch of Thamnograptus with the generative individuals, and the saclike appendages could be gonothecae. For any positive determination of the systematic position of this graptolite, however, the discovery of better material must be awaited.

PHYCOGRAPTUS Gurley

Dr Gurley has published [1896, p.89] the following diagnosis of this genus:

Polypary consisting of long, slender, flexuous stems, apparently simple, with an entire border and many segmented contents. Each segment with a single, central pit, seemingly the mouth of a cell, the latter apparently excavated in the substance of the stem. Sicula and virgula unknown. When preserved the substance is carbonaceous. Type P. brachymera.

This genus forms one of a group the relation of which to the more typical graptolites is at present somewhat dubious. They are all of a carbonaceous texture and some in addition show pits, apparently the mouth openings of a cell of some kind, but there is at present no evidence that such cell is of the theca type found in the more typical graptolites.

Two species were described, viz: P. brachymera, as the genotype, and P. laevis.

To test the validity of this new genus, we have to examine its species. Of P. brachymera the following figure and description are given:

Greatest length observed, 175 mm; width 1 mm; number of segments in 25 mm, about 18; each segment as long as, or little longer than wide (rarely one and one half times as long); pit large.

Horizon and locality. Lower *Dicellograpsus* zone, Stockport, N. Y.

From this it can be inferred that the straight, simple margins, the segmentation and pits are the essential, or only features of the form. While we have not succeeded in finding Dr Gurley's type of this species in the Stockport collection which we have studied, other specimens showing exactly like characters as also like width and number of segments within 10 mm were found in the collection. These proved to be identical with many others which before had been observed by the writer in other Normanskill collections and laid aside on account of their peculiar aspect, but which invariably turned out to be frontal views of the branches of a Dicellograptus. There is no doubt in my mind that this species also is based on such material. In fact, I have before me specimens showing this aspect in one portion and that of a Dicellograptus in another. The apparent segmentation is produced in the flattening process of fossilization by the small interval between the anterior overhanging apertural margin and the excavation for the aperture in the next theca. When looked at in oblique light, the gradual rising of the theca towards the aperture can be still distinctly seen. The entire border is due to the rather large size of the common canal in Dicellograptus, whose edges are shown on the sides of the frontal view and the large pits are the internal apertures of the thecae, which shine through the perisark and in like preservation can be seen in many other genera. There occur in the same collection narrower Phycograptus — aspects corresponding to other species of Dicellograptus.

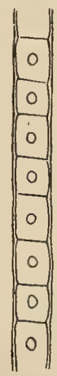

Fig. 150 Phycograptus brachymera Gurley. Copy of original figure (Jour. Geol. vol. 4, pl. 5, fig. 6)

If then P. brachymera, the genotype of the genus, is not a valid species, the validity of the genus rests on the next species. This, P. laevis, has been described by Hall as Graptolithus laevis. Its type and another specimen are in the American Museum of Natural History. Gurley describes the type [1896] as follows:

A careful examination of the type specimen shows that it is about 55 mm long, uniformly about 0.8 mm wide throughout. In one place a break occurs which, in the light of the other species, I incline to interpret as a segmentation, especially as the adjacent ends appear smoothly cut. Obscure traces of a median virgulalike chitinous thread are visible at intervals; no pits could be made out with certainty. The specimen is a mere film much wrinkled.

In another specimen I was able, however, to make out distinctly all the essential *Phycograptus* characters, viz, segmentations, pits, marginal grooves; and, in addition what appeared to be traces of a central chitinous virgula-like thread.

Horizon and locality. Utica shale, Turin, Lewis co., N. Y. Two specimens in American Museum of Natural History.

Hall's type shows no structure whatever and the second specimen only a few longitudinal threads. The latter I take to be sponge spicules, the whole probably representing a very slender sponge. This sponge is evidently conspecific or at least congeneric with another like slender flexible form, which is found attached in bundles to shells of the Utica shale (e. g. Schizocrania filosa) and of which a group contained in the National Museum has been labeled by Dr Gurley as "Phycograptus junciformis." I have obtained the same form in the Utica shale near Dolgeville. These specimens distinctly contain straight, carbonaceous, longitudinally placed sponge spicules and in some places small patches of squarish meshes of spicules and most probably represent a hitherto undescribed sponge.

If the writer's contention is correct that the genotype of Phycograptus is but the frontal view of a Dicellograptus and the other species of the supposed genus not a graptolite, the genus Phycograptus has to be suppressed.

MEGALOGRAPTUS Miller

The genus Megalograptus has been erected by Miller [Cin. Quar. Jour. 1874, 1 : 343] for a supposed graptolite, characterized by very large, cylindrical fronds with spinose processes and covered with cellular openings. The type is M. welchi, occurring in the Richmond beds of Cincinnati. Dr Ulrich informs me that the types of this form are fragments of a crustacean that is identical or closely related to Echinognathus clevelandi Walcott and Professor Foerste has lately shown me a drawing — to be published in his forthcoming work on the Richmond fauna — of an excellently preserved specimen that clearly exhibits its crustacean nature.

Order II GRAPTOLOIDEA Lapworth

Suborder A GRAPTOLOIDEA AXONOLIPA Frech em. Ruedemann

Family DICHOGRAPTIDAE Lapworth

DIDYMOGRAPTUS McCoy

The morphology and phylogeny of Didymograptus have been fully noted in Memoir 7, since this group of forms not only clearly attains its full development but also proceeds far on the road to extinction in our lower graptolite beds. While we recorded 17 species from the latter, we find only 3 species left in the lowest zone of the upper beds and in the Utica shale Didymograptus has disappeared entirely. Of these three species two, viz: D. sagitticaulis and D. serratulus belong to the group with declined branches, and one, D. subtenuis has nearly horizontal or slightly reclined branches. None of them shows any indications of the rapidly approaching disappearance of this stage in the life history of the Dichograptidae, and two of them are even robust forms with very long branches and of very frequent occurrence in the Trenton shales.

Didymograptus sagitticaulis Gurley

Plate 14, figure 3

Graptolithus sagittarius (Hisinger) Hall. Pal. N. Y. 1847. 1: 272; pl. 74, fig. 1

Graptolithus sagittarius Walcott. Alb. Inst. Trans. v. 10. 1883. (1879, advance sheet. p.34)

Monograptus sagittarius Whitfield. Am. Jour. Sci. Ser. 3. 1883. 26: 380

Didymograptus sagittarius (Hall) Lapworth. Roy. Soc. Can. Trans. v. 5, sec. 4. 1886. p.180f, 183f

Didymograptus cf. sagittarius (Hall) Lapworth. Geol. Sur. Can. An. Rep't. Ser. 2, v. 3, pt 1. 1889. p.95B

Didymograptus sagittarius Walcott. Geol. Soc. Am. Bul. 1890. 1: 338

Didymograptus sagittarius Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3: 411

Didymograpsus sagitticaulis Gurley. Jour. Geol. 1896. 4: 68

Didymograpsus convexus Gurley. *Ibid.* p.67; pl. 5, fig. 8

Didymograptus sagittarius Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33

Hall has, in the first-cited publication, identified a graptolite from the Normanskill shale of the neighborhood of Albany with Prionotus sagittarius Hisinger. Lapworth recognizing the specific distinction of the two forms has henceforth cited the American species as Didymograptus sagittarius (Hall). Gurley has proposed [1896, p.68] the new name, "sagitticaulis," to clear the synonymy; at the same time suggesting that "very possibly the species is a distal fragment of one of the others in the same beds, but if so, it is so far distal that the chances of connecting it with the proximal portion are rather small." An inspection of Hall's types — long fragments of branches — which are in the New York State Museum, leaves no doubt that they combine remarkable width (2.9 mm) with absence of an appreciable difference in width between the ends and hence are quite apparently far distal portions of a gigantic form. The shales of Mount Moreno have now furnished fragments of great length (fig. 151, 152 are enlargements of parts of one, 31 cm long) and these exhibit a gradual widening and distinctly connect in their characters and dimensions the thinner branches among Hall's types with the distal portion of a rhabdosome described by Gurley [1896, p.67] as D. convexus [*see* fig. 154]. Dr Gurley himself suspected this connection for he remarks: "Possibly it may be the proximal portion of D. sagitticaulis, but nearly fifty years have passed since the discovery of that species without the finding of any specimens long enough to connect the distal and proximal parts; hence the necessity for two names, at least pending the proof of such a connection which may be long delayed." It is very doubtful that

the finding of specimens of sufficient length to show the direct and continuous connection of specimens of the dimensions of Hall's types with the proximal parts will ever be accomplished, for from the rate of growth obtained from the long Mount Moreno specimens, we infer that the fragment representing Hall's type must have been at least 2.5 mm distant from the center.

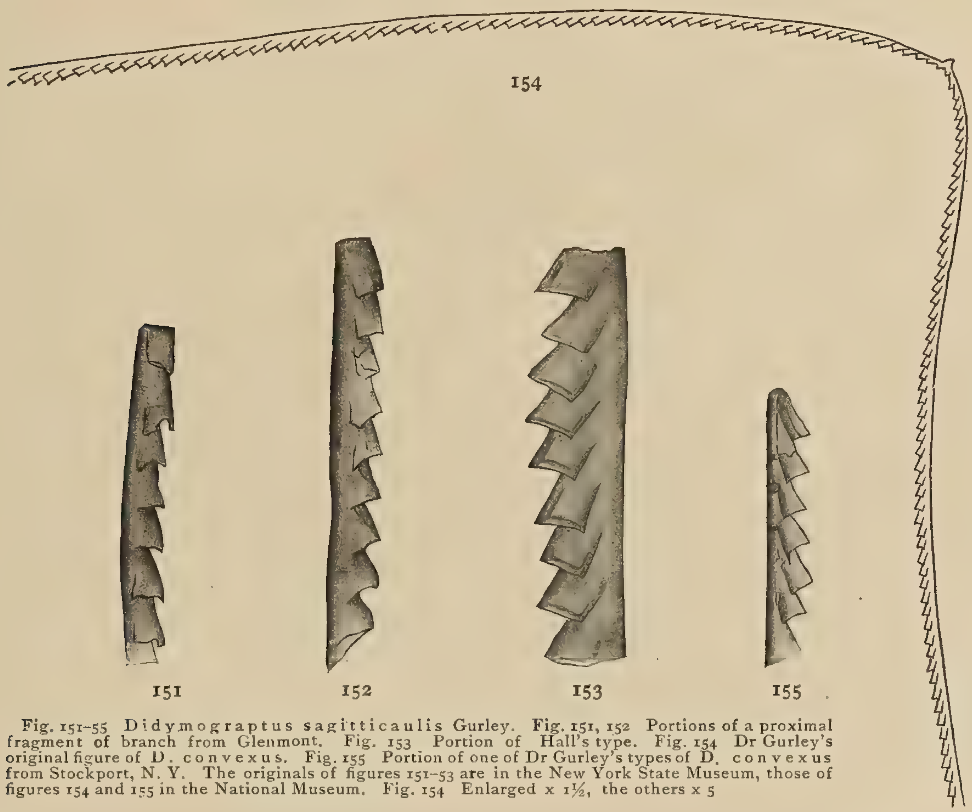

Fig. 151–55 Didymograptus sagitticaulis Gurley. Fig. 151, 152 Portions of a proximal fragment of branch from Glenmont. Fig. 153 Portion of Hall's type. Fig. 154 Dr Gurley's original figure of D. convexus. Fig. 155 Portion of one of Dr Gurley's types of D. convexus from Stockport, N. Y. The originals of figures 151–53 are in the New York State Museum, those of figures 154 and 155 in the National Museum. Fig. 154 Enlarged x 1½, the others x 5

We insert here camera drawings of a portion of Hall's type, of the initial and distal parts of D. convexus Gurley and of the intermediate stages from Mount Moreno to show the gradual transition in characters. This transition finds its clearest expression in the arrangement of the thecae. While in the widest of the types, only seven to eight thecae are counted in 10 mm and in D. convexus nine in the same distance (at the distal

extremity), a Glenmont specimen (here partly reproduced in figures 151, 152) has seven to nine of them. The distinguishing characters of D. sagittarius, notably the short, broad form of the thecae, their large overlap and large inclination differ little between the proximal part (D. convexus) and the largest, distal fragments. We therefore believe that we can hardly err in combining these specimens to obtain the following description:

Description. Rhabdosome consisting of two broad, long branches (initial width .3 mm; greatest width 2.9 mm; length by inference 2.5+ m), which in the proximal part rapidly increase in width (in 50 mm from .2 to 1 mm), but more distally are of nearly uniform width; are declined in direction, gently convex in the proximal portion, but early assuming a rigidly straight direction; forming an angle of inclination of 110° in the proximal part and one of 80° a little more distally. The sicula is very small (length = .8 mm) and inconspicuous but relatively broad. The first theca appears to originate in the apical part; this and the second theca (which, as far as the evidence of the single specimen available goes, originates from the first also near the apical extremity) diverge just above the aperture of the sicula. The crossing canal is horizontal. The earlier thecae are narrow and slender; they number nine in 10 mm, overlap not more than one quarter their length, and are inclined but 15–20°; but overlap and inclination increase very rapidly and the thecae become rapidly wider. In the mature parts there are but seven thecae in 10 mm; these overlap one half their length, are almost half as wide as long and are inclined at an angle of 25°. The outer margin is straight or gently convex; the apertural margin likewise or slightly concave and rectangular on the axis of the theca.

Position and localities. The type locality of the species is the Normanskill (Kenwood) near Albany and its horizon the Normanskill shale. It is there associated with D. subtenuis, etc. Hall knew the species also from the town of Stuyvesant and the neighborhood of Hudson. At the latter place it is common in the shales at Mt Moreno. It also occurs at Stockport, near Poughkeepsie, in Canada, Arkansas and on the Dease

river in British Columbia; in all of these places in the same horizon (Dicellograptus zone) as at the Normanskill, with the exception perhaps of the last mentioned locality.

Remarks. No other species of Didymograptus to which this gigantic form could be compared occurs in the Trenton shales. It is certainly a peculiar fact that a form attaining such relatively immense length and width should still appear at the very close of the hemera of the genus.

Hall has compared a considerably older and smaller form (D. similis from the Quebec and Deepkill shales, *see* Mem. 7, p.677) with this species and a comparison of the measurements emphasizes still more the similarity of their thecal form.

Didymograptus serratulus (Hall)

Plate 13, figure 4

Graptolithus serratulus Hall. Pal. N. Y. 1847. 1: 274; pl. 74, fig. 5a, b

Graptolithus serratulus Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.35)

Graptolithus serratulus Hall. N. Y. State Cab. Nat. Hist. 20th Rep't. 1867. p.223f

? Graptolithus (Monograptus) serratulus Whitfield. U. S. Geog. Sur. 100th Mer. Lieut. Wheeler's Rep't. 1877. 4: 19

Didymograptus serratulus Walcott. Geol. Soc. Am. Bul. 1890. 1: 338

Didymograptus serratulus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3: 411

Didymograpsus serratulus Gurley. Jour. Geol. 1896. 4: 295

Didymograptus serratulus Roemer & Frech. Lethaea pal. 1897. 1: 589

Didymograptus serratulus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.497, 541

Didymograptus serratulus Elles & Wood. Monogr. Brit. Grapt. pt 1. (in Pal. Soc. 1901). p.29; pl. 2, fig. 7a, b

Non Didymograpsus serratulus Nicholson. Geol. Soc. Quar. Jour. 1868. 24: 136

Non Didymograpsus serratulus Nicholson. Ann. & Mag. Nat. Hist. Ser. 4, v. 5. 1870. p.343; pl. 7, fig. 3, 3d

Description. Rhabdosome consisting of two straight or gently convex branches, which inclose an angle of 140°–155° (typically 140°), attain a length of 8+ cm, gradually broaden from .5 mm to 1.2 mm. Sicula long

(2.5 mm) and conspicuous, furnished with short, stout nema, that sometimes widens and terminates club-shaped. Primary thecae originating near the aperture and diverging below at the level of or below the latter. Thecae numbering 10 in 10 mm in proximal part and 8 to 9 in the same space more distally; three to four times as long as wide; overlapping two fifths their length in the proximal and one half in the distal portions, inclined at angles increasing from 18° to 30° in distal direction. Apertural margin straight, slightly inclined to axis, producing an acute denticle.

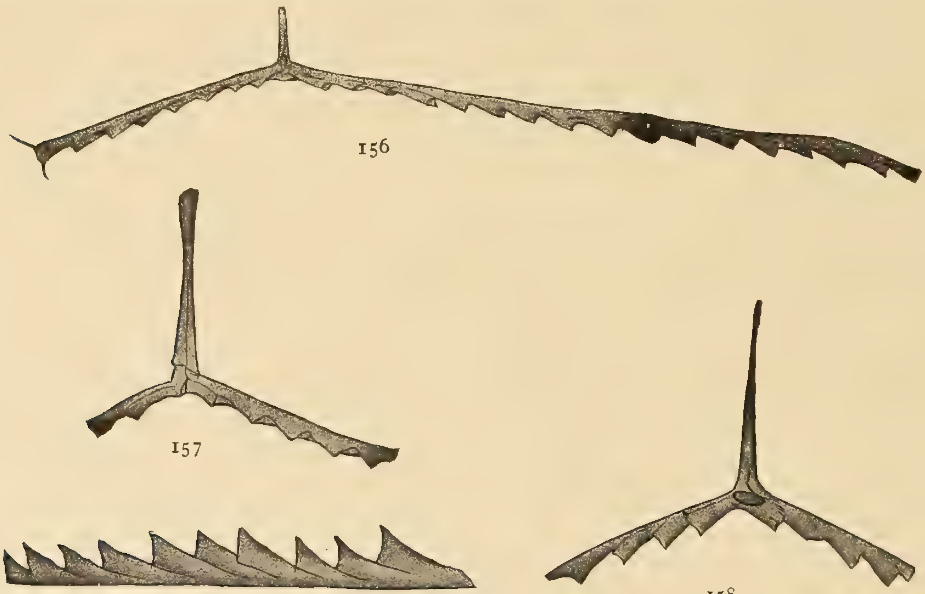

Fig. 156–59 Didymograptus serratulus (Hall). Fig. 156 Proximal portion of the variety juvenalis. Fig. 157, 158 Proximal portions of typical specimens. Fig. 158 That of the counterpart of the type specimen (in New York State Museum). Fig. 159 Distal portion of same specimen. All x 5

Position and localities. The type of this species is from the Normanskill shale at Kenwood near Albany. The same slab bears the cotype of D. subtenuis and specimens of Nemagr. gracilis, N. gracilis var. surcularis, Climacogr. parvus and Lasiogr. mucronatus. The species occurs also at Stockport, Columbia co., in association with Dicranogr. ramosus, Didymogr. sagitticaulis, Climacogr. parvus and Retiogr. geinitzianus, and at the power house north of Lansingburg. It is rare in these localities and has not been

observed in others. Its citation from the Utica shale of the Mohawk valley is probably erroneous [*see* p. 35]. Gurley has also recognized it in the shales of the novaculite area in Arkansas and Elles and Wood record it (probably in a variety) from the Glenkiln shales of S. Scotland and N. Ireland.

Remarks. D. serratulus is well characterized by its large sicula, its straight branches, and narrow, but rather rapidly widening branches (a feature not well brought out in the original drawing of the species). A varietal form is represented by a single specimen from the shales at Kenwood [fig. 156]. In this the thecae retain their nepiastic character for a longer time and in consequence of this the branches remain as narrow as in the sicular region of the typical form, lack the rigidity of those of the typical serratulus and form a larger angle of inclination (150°) while the sicula possesses the characteristic long form of the species. This variety may be distinguished as D. serratulus var. juvenalis. We are also certain that the form referred by Elles and Wood to D. serratulus is at least varietally distinct, for it possesses a smaller angle of inclination, uniform width of branches and more loosely arranged thecae (7 to 8 as against 9 to 10 in the typical material).

Didymograptus subtenuis (Hall)

Plate 14, figures 1, 2

Graptolithus tenuis (Portlock) Hall. Pal. N. Y. 1847. 1: 272; pl. 74, fig. 2a–d

Graptolithus subtenuis Hall. In Miller's Am. Pal. Foss. Ed. 1. 1877. p.244

Graptolithus subtenuis Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.35)

Dicellograptus tenuis Lapworth. Roy. Soc. Can. Trans. v. 5, sec. 4. 1886. p.178

Leptograptus tenuis Lapworth. *Ibid.* p.183

Leptograptus subtenuis Walcott. Geol. Soc. Am. Bul. 1890. 1: 338

Leptograpsus subtenuis Gurley. Jour. Geol. 1896. 4: 296

Didymograptus tenuis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p. 540f

Description. Rhabdosome consisting of two very thin (initial width .2 mm) and very slowly widening, slightly flexed, nearly straight branches, which attain great length (fragments of branches 20+ cm long quite

frequent) and in the proximal part diverge horizontally, increasing their divergence immediately after their origin to 200°–225°. The sicula is very short (.4 mm) and inconspicuous; the primary thecae diverge near the aperture of the sicula; their origin and connection have not been made out. The thecae in the initial part of the branches are extremely slender, six times as long as wide, 1.6 mm long, numbering 6 in 10 mm, and hardly overlapping. Their inclination is there but 5° and the branch has therefore a threadlike appearance. In the mature parts the thecae number nine in 10 mm, overlap one third their length and possess an inclination of 12°–15°. The outer margins are straight; the apertural margin is straight and rectangular on the axis of the theca.


160


161

Fig. 160, 161 Didymograptus subtenuis (Hall). Proximal and distal portions of the type specimen. x 5

Position and localities. The type specimens are from the Normanskill shale at Kenwood, where they are associated with D. sagitticaulis, Nemagr. gracilis, N. gracilis var. surcularis, Dicellogr. ramosus, Climacogr. parvus and Lasiogr. mucronatus. We have also found this species in the same horizon at Mt Moreno; and the collection from Stockport contains a few specimens. It has also been recorded from the rocks of Canada by Lapworth.

Remarks. Hall had at first identified his types with one of Portlock's species, but, on finding them specifically different, proposed the name subtenuis for the American form. Since he has not described the form so that it could be recognized from the description but rather relied on his reference to Portlock's species and several forms occur which though in a general way similar, are generically distinct, it becomes necessary to redescribe the species and restrict it to the specimens figured by Hall and which are in the New York State Museum. The latter [pl. 13, fig. 1, 2] show that the species is distinguished from all similar slender associates by the extreme thinness of the proximal portion and the remarkable slenderness of the thecae. In this character as also in the small size of the sicula it reminds one more of D. gracilis Törnquist, an older species of the

Deepkill beds, than of any other form and a comparison of their dimensions furnishes proof of their phylogenetic relationship.

For this reason, I have also referred this species to Didymograptus instead of to Leptograptus, as Lapworth has done. Hall's types do not show any of the characters either of the proximal part (two crossing canals) or of the thecal form (sigmoid curvature and introverted aperture), cited as diagnostic for the genus Leptograptus in the *Monograph of British Graptolites.* On the other hand, while D. subtenuis is by no means common in any of the localities, there is found in the same beds in much greater frequency a mutation of Leptograptus flaccidus (here described as L. flaccidus mut. trentonensis). The latter, from its general form and by comparison with Hall's figures — which, where the types are not at hand, alone are available for identification — might easily be taken to represent D. subtenuis. Lapworth has inserted in his manuscript report on the Stockport graptolites a full description of "Leptograptus tenuis," that completely tallies with the latter mutation, and since it is added, that L. tenuis is nearest related to L. flaccidus, there is little doubt that these two similar forms of our Normanskill shale have not been separated.

While fragments of the mature branches of D. subtenuis and Leptograptus flaccidus mut. trentonensis are not always distinguished with ease, the initial parts of their rhabdosomes are widely different [*comp.* fig. 160 and 172]. On the other hand, the proximal portion of the rhabdosome in our species is very similar in aspect and dimensions to that of Nemagraptus exilis var. linearis, but a comparison of the siculae and the form of the thecae will readily show their distinctness.

Didymograptus ? elegans (Emmons)

Monograpsus ? elegans Emmons. Am. Geol. v. 1, pt 2. 1856. p. 106–7, pl. 1, fig. 27

Original description. Outer edge of the serrations straight and nearly parallel with the opposite edge; depth of the serration equals one half of the width of the stipe. Figure 14 enlarged. The width of the stipe is

about $\frac{1}{16}$ inch and there are 24 cells in an inch. The substance of the graptolite is green and coriaceous. This beautiful species occurs in Augusta county, Virginia, in soft whitish shales.

Gurley remarks to this species in his manuscript:

This is a most wretched species, founded upon the worst possible material. It has every appearance of consisting of accidentally juxtaposed fragments of two (possibly, perhaps probably, distinct) Didymograpti. Nothing at all can be determined in regard to it until collections are available from the type locality.

Didymograptus rectus (Emmons)

Monograpsus rectus Emmons. Am. Geol. v. 1, pt 2. 1856. p.107, fig. 28

Original description. Straight, serrations pointed, upper edge of a serration oblique to the axis of the stem. Width of a serration equals one half of the width of the undivided part of the stem; width of the stem $\frac{1}{8}$ inch, and 22 crenulations in an inch, whose edges are perfectly straight and not curved so as to leave a curved space between the notches.

From the point of each crenulation there runs an oblique ridge which meets a longitudinal one, the latter runs nearer the straight than the crenulated margin. This species occurs in Columbia county, in the Taconic shales and is closely allied to G. latus of McCoy.

Gurley remarks to this species:

This species is without doubt a *Didymograptus*. Beyond this nothing at present can be said.

We may add that, since the type has been lost, and the description and figure are not sufficient for identification — especially if it is taken in consideration that in Columbia county graptolite shales from the Beekmantown to the Trenton horizons are exposed and the form in question may have come from any of these horizons —, it would seem most practical to drop this unrecognizable species altogether.

AZYGOGRAPTUS Nicholson

The trend of development of the great graptolite family Dichograptidae has been a most peculiar one, as we have fully set forth in Memoir 7 [*see ibid.* p.553]. The family began with highly multiramous forms and progressed steadily through various stages to forms with less and less branches. The last stage noted in the lower graptolite beds of this State

was the two branched Didymograptus. In Europe one has known for a long time a last and final stage in which still one of these two last branches has been lost and the one branched stage been reached that is known under the generic term Azygograptus.

Professor Lapworth has recognized a form of this type in the Normanskill shale material from Stockport, N. Y. sent to him by Dr Gurley for investigation and has described it as A. ? walcotti. We have referred here another form, A. ? simplex, with some doubt to this curious genus, our doubt being mainly due to the fact that we have no conclusive evidence that this fossil is not a growth stage of a larger, unknown graptolite. As we know it, it consists, in its most complete form, of the sicula and one theca only. If this be the mature organism, then it certainly represents the last possible stage of reduction — save the mere sicula — in the Dichograptidae, the last remaining branch of the once richly branching rhabdosome being reduced to but one theca.

Fig. 162 Azygograptus ? walcotti Lapworth. Original camera enlargement by the author of the species. x 6

Azygograptus ? walcotti Lapworth

Gurley has published [1896, p.69] the following description of this form from Lapworth's manuscript:

Polypary unilateral, monoprionidian, consisting of a single flexuous and simple compressed branch proceeding almost horizontally from the side of an inconspicuous sicula, 50 to 75 mm in length, in average diameter about 0.5 mm. Thecae 16 in 25 mm, without overlap, consisting of conical tubes, increasing slightly in diameter throughout, adnate to the coenosarcal canal, with straight or slightly convex ventral margins. Apertural margin a little inclined and projecting from the ventral margin for a distance equal to about one half the diameter of the polypary and transgressing upon the periderm for a similar distance. Denticle almost rectangular; excavations and interspaces shallow and inconspicuous.

and added the following comment:

This form has all the appearance of belonging to the curious genus *Azygograptus*. Two specimens occur in the collection. One lacks the proximal part; in the other there is evidence of the unilateral nature of the polypary and of the presence of the sicula. Further research may show that it belongs to the bilateral genus *Leptograptus*, but in any case it is a new and undescribed form of the family. If it actually belongs to *Azygograptus*, this is the first specimen of the genus on the American side of the Atlantic, and there is special appropriateness in its dedication to Mr Walcott, whose recent researches have done so much to elucidate the sequence and fossils of the strata in which it occurs.

Dr Gurley has not published any figures with the original description, nor have we been able to find the two type specimens mentioned in the description. Professor Lapworth has, however, furnished a camera drawing of the type with his manuscript which we take the liberty of reproducing here. We have not found any other specimens which could be identified with this species.

Azygograptus ? simplex sp. nov.

Plate 14, figure 10

The Normanskill shale has furnished in various outcrops, notably at Mt Moreno, at Glenmont near Albany and at the power house near Lansingburg, a considerable number of elongate triangular bodies which have the form and structure of siculae but are of such size that they can not be referred to any of the associated graptolites. Moreover, they frequently occur alone in the shale and they have not been observed to produce more than one theca. With our present knowledge it is therefore to be inferred that they either represent the sicula of a gigantic form which at present is unknown, or that they belong to an independent species of a group that in the process of reduction has gone so far beyond Azygograptus that only one theca is left of the branch and the whole rhabdosome, as a rule, consists only of an overgrown, so to say, sicula. We incline to the latter view on account of the failure of finding more advanced growth stages in even very large collections.

We have at one time [N. Y. State Mus. Bul. 42, p.520ff] identified these interesting organisms provisionally with Dawsonia campanulata

Nicholson [Ann. & Mag. Nat. Hist. 1873, 11 : 142] with which they have a considerable external resemblance and are also roughly contemporaneous. But on further study the fact that Lapworth cites the latter among the crustaceans [1876, p.7; 1877 expl. of pl. 7], while our form is undoubtedly a graptolite, and that both authors here mentioned figure the Scottish species throughout with an abruptly set-off proximal mucro and a jagged, broken-off distal margin, while the form here described has normally a regularly expanding body and only under abnormal conditions exhibits the other shape and also has a straight, smooth aperture, do not warrant any further identification of the Normanskill and Scottish species [*see* text fig. 171].

Our material of A. ? simplex furnishes the following descriptive data:

Description. Rhabdosome consisting of large, broad sicula (dimensions: length 5 mm; width 1.4 mm) with straight, transverse apertural margin and one theca which originates near the middle of the sicula and growing forward adheres to the sicula as far as the latter's aperture, then diverging slightly from the direction of the sicula. The theca is tubular, of about the same dimensions as the sicula and also lacking apertural processes.

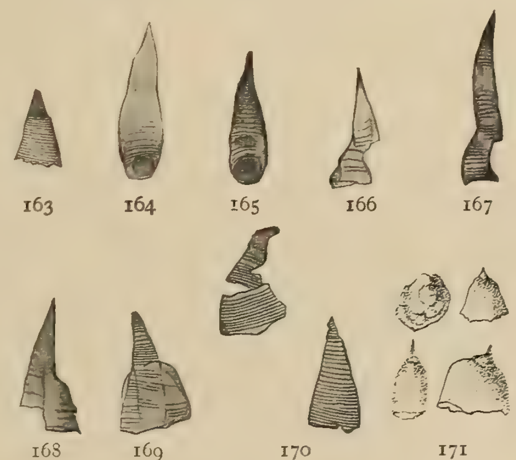

Fig. 163–70 Azygograptus ? simplex sp. nov. Fig. 163–65 Siculae. Fig. 166–68 Rhabdosomes. Fig. 169, 170 Specimens which burst open x 3. Fig. 171 Dawsonia campanulata Nicholson. (Copies from Lapworth)

Position and localities. This species has been observed by the writer in the Normanskill shales at Kenwood, Glenmont, Mt Moreno and Lansingburg. It is most common at Mt Moreno, but best preserved at Kenwood and Lansingburg.

Remarks. It should be noted that the form of the bodies here described is subject to some variation, obviously due to conditions of preservation. Some specimens may, e. g. assume a shape somewhat similar to D. cam-

panulata. This approximation is, as figure 169 shows, due to a splitting of the sicula and theca and subsequent flattening out of the parts, but in no case does it assume the bell or cuplike shape of D. campanulata, as figured by Nicholson and Lapworth.

There is also a possibility that this form is an aberrant Corynoides, but the extreme simplicity of its characters does not, for the present, warrant a definite conclusion as to its taxonomic position.

In the Normanskill shale of Schuylerville, Saratoga co., in a band of very fine grained shale, numerous bodies occur which in shape and size recall D. acuminata Nicholson. They are noted in the addendum.

Family LEPTOGRAPTIDAE Lapworth

LEPTOGRAPTUS Lapworth

Hopkinson already recognized with great acumen the fact that Graptolithus flaccidus Hall could be referred to neither Didymograptus nor Dicellograptus and Lapworth proposed the generic term Leptograptus for the important group which it represents and which he found to be characterized by the form of its thecae. It has the latter in common with Pleurograptus and Amphigraptus, all of which were united in the family Nemagraptidae.[1] Elles and Wood have elaborately described the characters of the genus and clearly pointed out its relations to Didymograptus and Dicellograptus. The facts which stand out as especially important from the description, are the elongated sigmoid curvature of the thecae, whose apertures are situated in depressions and are slightly introverted, and the recognition of the presence of two crossing canals at the base of the stipes. We have already discussed these characters and their phylogenetic bearing in the introductory notes on phylogeny.

The only representatives of Leptograptus in the faunas of New York are an earlier mutation of the genotype, two of its varieties; and L. annectans.

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[1] Subsequently replaced by the more appropriate term Leptograptidae.

Leptograptus flaccidus (Hall) mut. **trentonensis nov.**

Plate 14, figures 6, 7

Description. Rhabdosome attaining great length (branches of 27+ cm not rare); branches slender and flexed, first convex, then gently concave or mostly straight and horizontal, frequently drifted into thick bundles of parallel branches [fig. 7 part of one]; diverging in the proximal region at an angle of 220°–240°, having an initial width of .4 mm, and increasing gradually to a width of 1 mm, which is then maintained. The sicula measures 1.5 mm. It often bears a long (.8 mm) needlelike, apertural spine

172

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Fig. 172–75 Leptograptus flaccidus mut. trentonensis nov. Fig. 172 Obverse view showing long virgella. Fig. 173, 174 Reverse views of the sicular end. Fig. 175 Copies of Lapworth's (manuscript) enlargements of L. subtenuis from Stockport, N. Y. [*see* p. 255]. Figures 172–74, x 5; figure 175, x 8

(virgella). The first theca originates in the apertural half of the sicula and the next close to the budding point of the first. The four primary thecae diverge horizontally from the apertural part of the sicula. They are furnished with distinct mucros. The thecae are narrow and long, number 7 to 10 in 10 mm (the variations in the proximal portions of the branches amounting to 8 to 10 in different specimens and those in the distal parts to 7 to 8), and overlap in the proximal portion of the branches about one third their length, in the mature portion one half. They exhibit when seen in profile a small angle of inclination (15°) and a normally straight or slightly concave aperture that is slightly introverted and opens within a shallow short excavation.

Position and localities. L. flaccidus mut. trentonensis occurs in excellently preserved specimens, but not in great number in the Normanskill shale at Glenmont, with Diplogr. angustifolius and Cryptogr. tricornis. In great profusion it is found in a layer of the same horizon at Mt Moreno, forming sometimes bundles of 40 and more of parallel specimens; the branches extending horizontally in both directions from the sicula [fig. 7]. It is there associated with Diplogr. foliaceus and dense masses of Thamnogr. capillaris. The typical expression of the species is on this continent known only from the Utica shale of Lake St John in Canada. It is also a common form in the Hartfell shales of Great Britain where it produces no less than five varieties.

Remarks. From its general aspect one will unhesitatingly recognize in this mutation the later Leptogr. flaccidus and an inspection of the central part and character of the thecae bears out this identification. Moreover are also some of the varieties of the Hartfell shales already developed in the Normanskill shale. Compared with the Utica form, the Trenton mutation is a little thicker, but the difference would seem hardly sufficient to deserve recognition were it not for the occurrence of the New York form in a different formation.

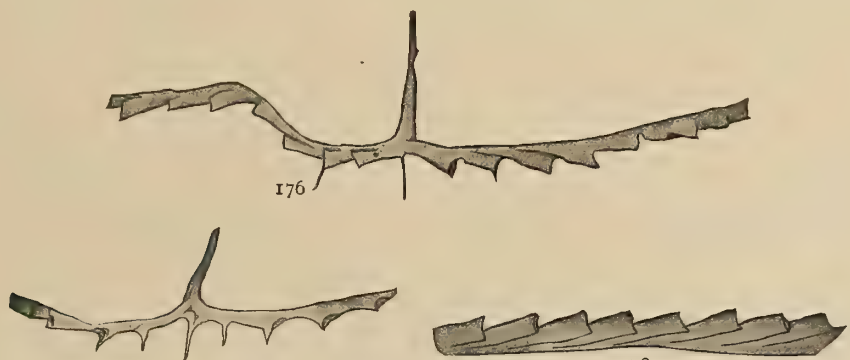
Leptograptus flaccidus (Hall) var. **spinifer** Elles & Wood mut. **trentonensis** nov.

Plate 14, figures 8, 9

Leptograptus flaccidus var. spinifer Elles & Wood. Monogr. Brit. Grapt. pt 3 (Pal. Soc. 1903). p.108; pl. 14, fig. 2a–c

This striking variety differs, according to the original description, from the typical species, "in the mode of origin of its stipes, its more irregular curvature, its longer sicula and the more conspicuous spines on the proximal thecae." The figures here given of the New York specimens distinctly show all of these characters except the budding of the first thecae. The sicula is very long (2 mm, *see* fig. 176) and gradually tapering. Its aperture is furnished with a long, often needlelike, virgella. The first four

thecae bear long apertural spines, which in some specimens are extremely slender (176), in others relatively stout (177). The branches are first broadly convex, then slightly concave, but mostly approach a straight line and appear rather rigid when compared with those of the type of the species. This feature they exhibit in a still stronger degree than the British representatives of the variety spinifer, although they do not exceed them in final width (1 mm).



176 177 178

Fig. 176–78 Leptograptus flaccidus var. spinifer mut. trentonensis nov. Fig. 176, 177 Reverse views of the sicular end showing its spinose character. Fig. 178 Enlargement of mature portion of branch. x 5

While the British variety, as well as the typical species occur only in the Hartfell shales, the New York representatives have been observed only in the older Normanskill shale (Glenmont, N. Y.). It is mainly for this reason that we emphasize the slight difference in relative rigidity of the branches.

Leptograptus flaccidus (Hall) var. **spinifer** Elles & Wood mut. **trifidus** nov.

A unique specimen [fig. 179] showing the characters of L. flaccidus var. spinifer was collected by the writer at Mt Moreno. It possesses between the sicula and the branches a strong carbonaceous web. The whole central portion is evidently much thickened, and from its lower side three processes are suspended, two of which terminate bluntly, while the middle one tapers to a point and may represent a hypertrophic virgella. The processes are longitudinally wrinkled and do not seem to have been composed of thecae.

We see in this interesting variety a similar feature as is observed in

the var. ornatus of Dicellograptus complanatus which occurs in the Upper Hartfell shales of S. Scotland. Of this variety it is stated in the *Monograph of British Graptolites*, part 4, page 141, that "in some specimens these two primary thecae appear to have been entirely modified to stout spines which have a length of 4 mm–4.5 mm." In our specimen the virgella seems to have been likewise developed abnormally (to a length of 5 mm) and the primary thecae also modified into large apertural winged spines. The proximal halves of the three spines are connected by a web

Fig. 179 Leptograptus flaccidus var. spinifer mut. trifidus nov. The type specimen enlarged x 5

and the entire center of the rhabdosome is thickened by peridermal layers apparently to serve as a basis for the spines.

Leptograptus annectans (Walcott)

Plate 14, figure 5

Graptolithus annectans Walcott. Utica Slate and Related Formations. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.20, 35; pl. 1, fig. 2, 2a)

Graptolithus tenuis ? (Portlock) Ulrich. Cat. Foss. occur. in Cin. Gr. etc. 1880

Leptograptus annectans Ami. Can. Rec. Sci. 1893. 9: 180

Leptograptus annectans Lapworth. Roy. Soc. Can. Trans. 1886. 4: 183

Leptograptus annectans Gurley. Jour. Geol. 1896. 4: 296

Description. Rhabdosome of medium size, branches attaining a length of 50+ mm and showing gentle double curvature (first concave and then

convex), gradually increasing in width from .3 mm to about 1 mm, angle of divergence 270°–290°. Axil wide, sicula small (1.3 mm) provided with a small virgella. Four primary thecae approximately horizontal, bearing small mucros. Thecae numbering 10 in 10 mm with slight variations (11 to 12 near center); overlapping about one half their length, inclined 15°; the ventral walls of the free portions of the thecae first straight, slightly convex near the aperture; the latter is slightly introverted, the excavation shallow.

Position and localities. Walcott obtained the type of his description from the Utica shale in the town of Trenton, Oneida co., N. Y. The State Museum contains a slab from the type locality (Holland Patent, Oneida co., N. Y.) bearing a great number of rhabdosomes in association with Triarthrus becki. We have nowhere else observed it in the Utica shale of New York and consider it therefore a rare form.

Dr Ulrich has sent me two small fragments [*see* fig. 182] which he collected in the "true Utica shale" at Cincinnati, Ohio, and once had cited with doubt as Graptolithus tenuis Portlock. They fully agree with Walcott's species in their characters. Gurley has also listed the form as doubtfully occurring in the Lower Dicellograptus zone of Arkansas and in the lower Cincinnati beds. The Arkansas material to which he had access is not in such a condition as to permit positive identification and the reference to the lower Cincinnati is probably also based on the Ulrich collection.

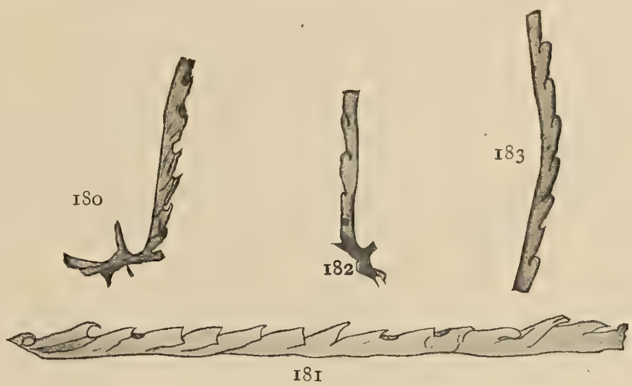


Fig. 180–83 Leptograptus annectans (Walcott). Fig. 180, 181 The sicular (reverse aspect) and distal portion of a specimen from the type locality. Fig. 182, 183 Two fragments from the Utica shale of Cincinnati. (Ulrich collection.) x 5

Remarks. Walcott states that the form and proportion of the stipe are similar to that of Graptolithus flaccidus Hall; but that the thecae are quite different. Close measurements of the dimensions of the branches

and thecae do not seem to bring out sufficient differences to warrant a greater than varietal differentiation of the two, though the excavations may be a little deeper and the introversion slightly greater than in L. flaccidus, but the principal difference lies in the form of the branches, whose curvature is opposite to that of L. flaccidus, i. e. first concave and then convex; the branches are furthermore strongly ascending in their direction, and therefore, in the majority of specimens, inclose a smaller angle (axil) between their dorsal walls. The sicula and the aspect of the proximal part of the rhabdosome are again suggestive of L. flaccidus with the exception of the upward growth, assumed by the third and fourth thecae. In these differential features, the form shows an approach to Dicellograptus.

SYNDYOGRAPTUS gen. nov.

Ety. σύνδυο in pairs, γράφω I write.

Rhabdosome consisting of two obliquely ascending main branches and symmetrically disposed, ascending, parallel secondary branches, which are given off in pairs. The thecae are of typical leptograptid character, with straight ventral margins, slightly introverted apertural part and shallow excavations. Also the structure of the sicular part of the rhabdosome seems to be that of a Leptograptus.

Genotype. Syndyograptus pecten sp. nov.

Although this genus in its general habit possesses considerable similarity to Pterograptus Holm, it differs distinctly from the same in the paired arrangement of the branches (in contrast to the serial arrangement of the branches in the Swedish genus), even if Pterograptus were not a dichograptid with pendant instead of ascending branches. The nearest leptograptid genus to Syndyograptus, as far as the general arrangement of the branches of the rhabdosome is concerned, is Amphigraptus Hall, which also possesses paired secondary branches. Their development, however, is so much concentrated at the center that a rhabdosome with radiating branches results. It would be only necessary that in Amphigraptus each pair diverge less widely and the rhabdosome would settle on its side as in Syndyograptus, the result being an aspect of the rhabdosome very much like that of the latter genus.

Syndyograptus pecten sp. nov.

Plate 15, figures 5, 6

Description. Rhabdosome of small size, consisting of two stipes from which at regular intervals paired secondary branches (12 or more) are given off. The former have a double curvature, they are at first gently convex for a short distance, and then concave. The angle of divergence of the convex part varies between 200° and 250° and is typically about 230°; the axil is wide and open. The stipes are narrow (.3 mm at origin) and of nearly uniform width (.5 mm at distance of 25 mm). The secondary branches are straight and ascending, the pairs slightly diverging. The first pair on either side of the center originates from the second theca of each stipe and they follow at intervals of about 2.5 mm or corresponding to

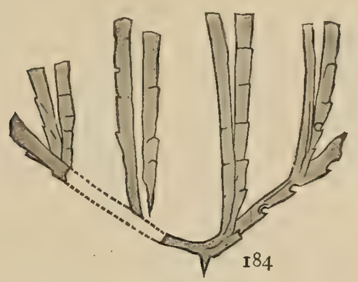


Fig. 184, 185 Syndyograptus pecten sp. nov. Two of the type specimens. Fig. 184 Showing the sicula. x 5

every third theca of the stipe, and widen more rapidly than the latter, attaining a width of .5 mm at a distance of 15 mm. The sicula is inconspicuous [*see* fig. 185]. Its length is about 1.2 mm; its slender virgella protrudes from the apex of the rhabdosome.

The relations of the primary thecae are obscure in the specimens; the first theca seems to bud from the middle of the sicula, to be rather short and to diverge but a short distance from the sicula, while the second theca grows horizontally for nearly its whole length. It has been seen to bear a short apertural spine. The third and fourth thecae are so situated, that probably two crossing canals passed the sicula. The thecae are slender and narrow, about six times as long as wide; they number mostly 10 in 10 mm, increasing to 12 in the proximal region; their overlap is one fourth

their length; the free ventral margin is straight and subparallel to the axis of the branch; the aperture slightly introverted and opening within a shallow excavation, that occupies one fourth to one third the width of the branch and one fourth the length of the free ventral margin.

Position and locality. In a layer of the Normanskill shale at Glenmont, N. Y. associated with Didymogr. sagitticaulis, Dicranogr. furcatus, Diplogr. foliaceus, Climacogr. parvus, Cryptogr. tricornis and Lasiogr. mucronatus. Besides two separate specimens, a slab from the same locality has been found in the New York State Museum, bearing this as the prevailing form [*see* pl. 15, fig. 5].

Remarks. Only one of the type specimens possesses more than two symmetric pairs of secondary branches, all the others have developed only the first pair on either side of the center of the rhabdosome, and some have none at all. In those with but two pairs, the secondary branches are very short, while the stipes are apparently preserved in full length. These facts would indicate that the secondary branches lagged much behind the stipes in their development.

PLEUROGRAPTUS Nicholson

The Utica shale of New York has furnished a single specimen representing the monotypic genus Pleurograptus, and this is so fragmentary that it is little suitable to serve as basis of an accurate description of the genus. We therefore insert here the diagnosis of the genus, given in the *Monograph of British Graptolites* at the hand of abundant material.

Polypary bilaterally symmetrical, consisting of two uniserial main stipes, which diverge from the sicula at angles slightly exceeding 180°, and from one margin (or both) of which numerous, usually irregularly disposed, secondary uniserial branches are given off. These secondary branches may be simple or compound.

Thecae of the type of Leptograptus.

The New York specimen [pl. 15, fig. 1] shows the arrangement of the secondary branches on one side of the main stipes and of the tertiary branches on one side of the secondary ones; as well as the slender character of the whole rhabdosome and the leptograptid form of the thecae [*see* fig. 186].

Pleurograptus linearis (Carruthers)

Plate 15, figure 1

Cladograpsus linearis Carruthers. Roy. Phys. Soc. Edinburgh. Trans. 1858. p.467, fig. 1

Cladograpsus linearis Carruthers. Ann. & Mag. Nat. Hist. Ser. 3, v. 3. 1859. p.24, fig. 3

Dendrograpsus linearis Carruthers. Geol. Mag. 1867. 4: 70

Pleurograpsus linearis Nicholson. Geol. Mag. 1867. 4: 257, pl. 15, fig. 1-5

Pleurograptus linearis Lapworth. Cat. West. Scott. Foss. 1876. p.5, pl. 3, fig. 69

Coenograptus (Pleurograptus) linearis Roemer & Frech. Lethaea pal. 1897. 1: 586, fig. 158

Pleurograptus linearis Clark. Geol. Mag. Ser. 4, v. 9. 1902. p.498

Pleurograptus linearis Elles & Wood. Monogr. Brit. Grapt. pt 3 (in Pal. Soc. 1903). p.119; pl. 14, fig. 7; pl. 17, fig. 1

Pleurograptus linearis Olin. Kongl. Fysiogr. Sällsk. Handl. N. F.. Bd 17. 1906

But a single representative of this common zone fossil of the Hartfell shales of Scotland has, to my knowledge, been found thus far in the Utica shale. It comes from Holland Patent, Oneida co., N. Y. and is now in the New York State Museum. This has been described by Gurley in his manuscript as follows:

Fig. 186 Pleurograptus linearis (Carruthers). Enlargement (x 4) of portion of branch of the Holland Patent specimen

Proximal end of rhabdosome not visible; main stem somewhat S-curved, giving off primary branches from the convex sides, at first at about a right angle and subsequently at a constantly diminishing angle. Primary branches curving gently distalward, giving off secondary branches at a much smaller angle than that at their own origin. Primary branches near origin 0.4 mm wide, distally 0.6 mm wide. The branches all increase slowly in width and measure *ad max.* 0.7 mm. Thecae proximally on main stem, 20 in 25 mm. Distally on branches, 25 in 25 mm.

The bases of the branches are as far apart (15 mm) as in the var. simplex (Lapw. manuscript) Elles & Wood, but the branches are not simple as in the latter. The thecae [*see* fig. 186] are long and slender; seven to eight times as long as wide, overlapping one half their length and inclined about 10°. The free ventral margin is straight, the apertural part introverted and opening within a shallow excavation.

The associated forms of this fossil are unknown.

AMPHIGRAPTUS Lapworth

In his valuable paper on an "Improved Classification of the Rhabdophora," Lapworth [1873, p.559] has erected and briefly diagnosed the genus Amphigraptus for the reception of a form described by Hall from the shales at the Normanskill as G r a p t o l i t h u s d i v e r g e n s. In the *Monograph of British Graptolites* [pt 3, 1902, p.121] the following diagnosis of Amphigraptus is given:

Polypary rigid, bilaterally subsymmetrical, consisting of two uniserial main stipes, diverging from the sicula at an angle of approximately 180°, which give off regularly or irregularly disposed, rigid, simple or compound secondary branches constituting a more or less radiate polypary. *Thecae* of the characteristic *Leptograptus* type, with low inclination and small amount of overlap.

It is further added that the secondary branches agree with the main stipes in all essential characters and that they are typically disposed in pairs.

"The genus Amphigraptus is," according to the Monographers, "somewhat rare in British deposits, and has only been found in the Hartfell Shales in the zones of D i c r a n o g. c l i n g a n i and P l e u r o g. l i n e a r i s and is exceedingly rare in the first named zone." Besides the genotype, A. d i v e r g e n s, a variety of the same and a second species, A. d i s t a n s, are distinguished.

The genus is also of extremely rare occurrence on this continent, for only two specimens of A. d i v e r g e n s have come to my notice, one the type of the species in the American Museum of Natural History and the other a specimen in the very large collection from the Normanskill shale at Glenmont, now in the State Museum. Besides this, the form described by Hall as G. m u l t i f a s c i a t u s may be also brought hither according to the broader diagnosis in the *Monograph of British Graptolites* which embraces forms with simple and compound secondary branches.

The paired branching, which is concentrated in the proximal portion of the main stipes and the leptograptid type of the thecae are distinctly shown in the enlargements here given of the type specimen of the genotype [*see* text fig. 188, 190].

Amphigraptus divergens (Hall)

Plate 15, figure 2

Graptolithus divergens Hall. Pal. N. Y. 1859. 3: 509, fig. 9

Graptolithus divergens Hall. N. Y. State Cab. Nat. Hist. 12th An. Rep't. 1859. p.57, fig. 9

Graptolithus divergens Hall. Can. Org. Rem. Dec. 2, 1865. p.12f, fig. 11

Graptolithus (Coenograptus) divergens Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.179, fig. 12

Amphigraptus divergens Lapworth. Geol. Mag. 1873. 10: 559

Amphigraptus divergens Lapworth. Cat. West. Scott. Foss. 1876. p.5; pl. 1, fig. 70

Amphigraptus divergens Lapworth. Quar. Jour. Geol. Soc. 1878. 34: 331

Amphigraptus divergens Lapworth. Ann. & Mag. Nat. Hist. 1880. 6: 18

Graptolithus divergens Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879, p.35)

Amphigraptus divergens Lapworth. Roy. Soc. Can. Trans. v. 5, sec. 4. 1886. p.184

Amphigraptus divergens Walcott. Geol. Soc. Am. Bul. 1890. 1: 338

Amphigraptus divergens Gurley. Jour. Geol. 1896. 4: 296

Coenograptus (? Pleurograptus, ? Pterograptus) divergens Roemer & Frech. Lethaea Pal. 1897. 1: 587

Amphigraptus divergens Elles & Wood. Monogr. Brit. Grapt. pt 3. 1903. p.122; pl. 18, fig. 1

Description. Rhabdosome of medium size, consisting of two straight or but slightly curved main stipes, diverging at about 180° from the sicula and several (as many as five) pairs of secondary branches, all of which are produced in close proximity to the centre. The main and secondary branches are thick (.8 mm–1 mm wide) of uniform width and rigid appearance. The sicula and primary thecae have not been made out; the thecae of the branches are very long (2 mm), number 8 to 10 in 10 mm, are six times as long as wide and overlap more than one half their length. Their free ventral margins are straight, the apertural margins introverted and opening within shallow and short excavations.

Position and localities. Hall records the form from the "shales of the upper part of the Hudson river group," giving no locality. His types came

from the Normanskill shale at Kenwood.[1] The New York State Museum also contains a specimen from the same horizon at Glenmont, N. Y., which is associated with Nemagr. gracilis and Climacogr. parvus. In Great Britain this species is recorded from a much higher horizon (zone of Pleurograptus linearis of the Hartfell shales). It would therefore seem to have been a long range form. It is of rare occurrence here and also in the Scottish beds.

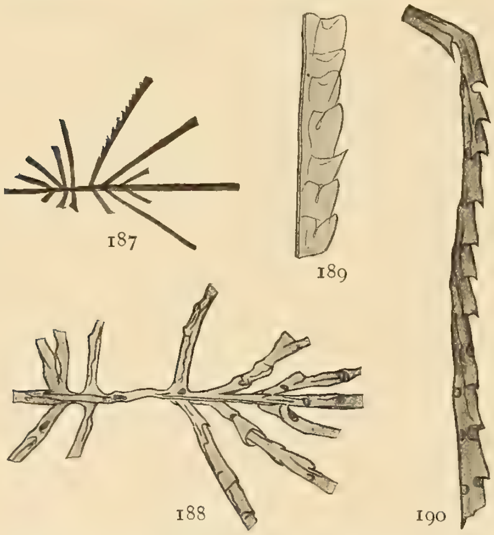


Fig. 187–90 Amphigraptus divergens (Hall). Fig. 187 Copy of original figure. Fig. 188 Enlargement of sicular or central portion of type. Fig. 190 Enlargement of branch of same. Fig. 189 Portion of branch of other specimen. x 5

Remarks. This is the sole representative of the peculiar genus Amphigraptus in our shales and with our present knowledge, in America. Its paired secondary branches are its most peculiar character. The mode of branching by which this apparently paired arrangement of the branches is produced, is too much obscured by the close budding to be observable.

The branches are so little compressed that they appear as tubes, where all other graptolites are completely flattened out. This results from their having been provided with an exceptionally thick periderm. To the latter fact the straight and rigid appearance of the branches, so characteristic of the form, is also due.

Amphigraptus multifasciatus (Hall)

Plate 15, figure 4

Graptolithus multifasciatus Hall. Pal N. Y. v. 3, sup. 1859. p.508; p.509, fig. 8

Graptolithus multifasciatus Hall. N. Y. State Cab. Nat. Hist. 12th An. Rep't. 1859. p.56; p.57, fig. 8

[1] In Memoir 7 this form has been erroneously cited as occurring in the Quebec shales of Point Levis [*Ibid.* p.701].

Graptolithus multifasciatus Hall. Can. Org. Rem. Dec. 2. 1865. p.10, fig. 7

Clematograptus multifasciatus Hopkinson. Geol. Soc. Quar. Jour. 1875. 31:652

Clematograptus multibrachiatus (Hall) Lapworth. Ann. & Mag. Nat. Hist. 1880. 6:20

Graptolithus multifasciatus Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879, p.35)

Clematograptus multifasciatus Lapworth. Roy. Soc. Can. Proc. & Trans. 1887 4:178

Clematograptus multifasciatus Walcott. Geol. Soc. Am. Bul. 1890. 1:338

Clematograptus multifasciatus Gurley. Jour. Geol. 1896. 4:296

In 1859 Hall described the proximal portion of a multiramous form from the Normanskill shale at Kenwood near Albany, which later on was referred to Clematograptus by Hopkinson. The species was based on a single specimen and no other seems to have been found here since. Lapworth cites it with a query in the *Annals and Magazine* from the Arenig but the species has not been mentioned again in the *Monograph of British Graptolites.* Since he also lists it among the Canadian species, we hope that our knowledge of this interesting form will be materially increased in his forthcoming work on the Canadian Graptolites.

We have been unsuccessful in obtaining the type specimen. Professor Whitfield has kindly informed us that it was originally found by Prof. George Washington Taylor and given to Hall after publication. It is now neither in the New York State collection nor the American Museum of Natural History and Professor Whitfield presumes that it has lately gone to the Museum of Chicago University with Hall's last collection. This collection, according to information from Professor Weller, is at present inaccessible.

We are then restricted in our conception of the species to the brief original description and figure [*see* pl. 15] which are here copied:

Body consisting of numerous bifurcating branches, which are arranged bilaterally on either side of a short strong central bar. The branches bifurcate irregularly and the subdivisions on one side amount to 21, and on the other to 22, while the specimen is far from being entire. The branches are serrated on one side, serratures somewhat closely arranged.

The specimen shows the lower or nonserrated surface, and several of the longer branches are turned sufficiently on one side to show the serrations in a tolerable degree of perfection.

As horizon is given the "shales of the upper part of the Hudson River group."

Assuming that the drawing is made with the care and exactitude by which Professor Whitfield's graptolite drawings excel, we can infer from it that the general structure of the rhabdosome is that of an Amphigraptus the secondary branches being disposed in pairs so closely at the proximal end that they assume a radial position; and that they exhibit the same rigidity and straightness as those of A. divergens, with the additional feature that the secondary branches divide again. But since the simple or compound structure of the secondary branches is especially cited among the diagnostic characters of the genus by the British monographers, this complication beyond the genotype does not exclude the form from the genus. The thecae seem also to possess, judging from the original drawing, the low inclination and small amount of overlap, characteristic of the leptograptid type of thecae.

Hopkinson had cited this species as the second representative of his genus, Clematograptus. It is, however, obvious from his figure that his genotype, Clematograptus implicatus, belongs to an entirely different family and is probably a dendroid form, and that hence the reference of the New York species to that genus is erroneous.

Subfamily NEMAGRAPTIDAE Ruedemann

NEMAGRAPTUS Emmons

(= Coenograptus Hall)

We have in the first part of the *Graptolites of New York* [Mem. 7, p.701] introduced a form from the Deepkill shales as representing a new genus and species (Sigmagraptus praecursor) and as being ancestral to the important genus here under discussion. At the same place we have proposed the new family Coenograptidae for the group of genera probably derivable from Sigmagraptus.

In the *Monograph of British Graptolites* the family Leptograptidae, based mainly on the morphology of the thecae, is given the compass it had when proposed by Lapworth in 1879. It there comprises both the pauciramous and multiramous forms, among the latter also Nemagraptus. While the family thus conceived contains a large variety of types of arrangement of branches, it is well defined by the form of the thecae and slender character of the branches, and clearly in equipoise with the other families, as e. g. the Dichograptidae.

With our present knowledge of the phylogeny of these forms it may not yet seem practicable to subdivide these large families. Nevertheless, we do not doubt that eventually the peculiar group of forms represented by Sigmagraptus and Nemagraptus will demand recognition as a subdivision of the family. In recognition of both, the general affinity of the Leptograptidae and the closer one of the group of genera here mentioned, we have united the latter in a subfamily of the Leptograptidae. Since the term Coenograptus has lost its validity to Nemagraptus we have termed this subfamily the Nemagraptidae.[1] Fuller details of the apparent phylogenetic relations of the genera of the Leptograptidae have already been given in the introductory chapter on phylogeny.

The genus here under discussion is currently known as Coenograptus Hall. Its genotype is Graptolithus gracilis, described by Hall in volume 1 of the *Palaeontology of New York* [1847]. It is set forth in the *Monograph of British Graptolites* that Emmons in 1855 described quite obviously the same form as Nemagraptus elegans, thus creating a synonym of Hall's species, but at the same time proposing a new generic name. The generic terms Stephanograptus and Helicograptus were then proposed for the same form about a decade later by Geinitz and Nicholson respectively. None of these names found recognition and Hall [N. Y. State Cab. 20 An. Rep't, 1868, p.217] proposed the generic term Coenograptus at about the same time, ignoring Emmons's and the others' earlier

[1] The term Nemagraptidae was originally applied to the Leptograptidae and being replaced by the latter term has become available for this subdivision.

names, though he had pointed out in 1865 that Emmons's species is "apparently a part of an individual of Graptolithus gracilis, or some similar species." Hall's name was generally accepted; the just application of the law of priority requires, however, the resurrection of Emmons's older name.

As to the mode of bifurcation in Nemagraptus, I do not find any notes in the literature other than that the secondary branches are thrown off of the main stipes opposite the apertures of the thecae. A few specimens of N. gracilis allow, by a slight infiltration of the basal parts of the thecae an insight into the mode of bifurcation [*see* fig. 191]. In these the new stolonal theca is seen to originate close to the aperture of the mother theca (about one fifth of the latter's length from the aperture) and to grow in the axial direction of the mother theca as far as the aperture of the latter, where the first theca of the secondary branch is produced from it. At this point both the mother and daughter theca change their direction, but so that the former diverges but a little to one side, conforming to the curvature of the main stipe, while the latter diverges so much (complement of angle of other) that both together form a right angle. It appears hence that N. gracilis, and presumably the whole genus, conform to the principle enunciated by the writer for Goniograptus [1902, p.583], viz, that "the bifurcations of the branches throughout the rhabdosome take place in the same manner as the formation of the main stipe by the sicula, viz, by the successive budding of two thecae, the second of which buds from the first, and both of which, assuming diverging directions, determine the direction of the branches." This principle quite apparently holds true for all Graptoloidea Axonolipa.

Fig. 191 Nemagraptus gracilis (Hall). Portion of specimen from the Normanskill. x 5

Figure 191 shows that the mother thecae of the secondary branches in N. gracilis bud alternately on opposite sides of the basal parts of the stolonal thecae, a feature which before has been pointed out by the writer [1904, p.564] in the discussion of the phylogenetic relations of Sigmagraptus and Nemagraptus.

In general aspect the mode of branching of Nemagraptus gracilis is truly monopodial or lateral, the slight diversion of the stolonal thecae from the axial direction of the mother thecae after their becoming free is however an indication of a trace of a former dichotomous mode of branching.

The genus is here restricted to the Normanskill shale where it occurs in two species with numerous varieties, viz:

Nemagraptus gracilis (*Hall*)
var. surcularis (*Hall*)
var. crassicaulis *Gurley*
var. distans *nobis*
var. approximatus *nobis*
Nemagraptus exilis *Lapworth*
var. linearis *nobis*

Nemagraptus gracilis (Hall)

Plate 16, figures 1–5

Graptolithus gracilis Hall. Pal. N. Y. 1847. 1: 274; pl. 74, fig. 6a–d

Rastrites barrandi Harkness. Geol. Soc. Quar. Jour. 1855. 11: 475

Nemagrapsus elegans Emmons. Am. Geol. pt 2. 1856. p.109; pl. 1, fig. 6

Graptolithus gracilis Hall. N. Y. State Cab. Nat. Hist. 12th An. Rep't. 1859. p.58, fig. 10

Graptolithus gracilis Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p.56, fig. 6, 7

Graptolithus gracilis Hall. Pal. N. Y. v. 3. sup. 1859. p.510, fig. 5–7

? Graptolithus gracilis Bailey. Geol. Soc. Quar. Jour. (Dublin). 1862. 9: 5; pl. 4, fig. 5

Graptolithus gracilis Hall. Can. Org. Rem. Dec. 2, 1865. p.13, 14, fig. 16–18

? Graptolithus gracilis Bailey. Mem. Geol. Sur. Ireland. 1866. Sheet 133, p.12, fig. 3

Stephanograptus gracilis Geinitz. Neues Jahrb. f. Mineral. 1866. p.124

Cladograpsus gracilis Carruthers. Geol. Mag. 1868. 5: 130

Coenograptus gracilis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.179–80, fig. 17–19

Helicograpsus gracilis Nicholson. Ann. & Mag. Nat. Hist. Ser. 4, v. 2. 1868. p.25, fig. 1

Coenograptus gracilis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. Rev. ed. 1870. p.211, fig. 17–19

Coenograptus (Helicograptus) gracilis Nicholson. Monogr. Brit. Grapt. 1872. p.45, fig. 14

Coenograptus gracilis Lapworth. Cat. West. Scott. Foss. 1876. p.5; pl. 3, fig. 65

Coenograptus gracilis Lapworth. Belfast Nat. Field Club. Rep't & Proc. Apx. 1877. p.142; pl. 7, fig. 11

Graptolithus gracilis Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.35)

Coenograptus gracilis Tullberg. Sver. Geol. Unders. Ser. C, no. 50. 1882. p.20

Monograptus gracilis Whitfield. Am. Jour. Sci. Ser. 3. 1883. 26: 380

Coenograptus gracilis Herrmann. Nyt Mag. f. Naturvidensk. 1885. 27: 359; pl. 2, fig. 21

Coenograptus gracilis Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4: 178f

Helicograptus gracilis Dodge. Am. Jour. Sci. Ser. 3. 1890. 40: 153

Stephanograptus gracilis Walcott. Geol. Soc. Am. Bul. 1890. 1: 338

Coenograptus gracilis Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3: 408

Stephanograptus gracilis Gurley. Jour. Geol. 1896. 4: 296

Coenograptus gracilis Roemer & Frech. Lethaea Pal. 1897. 1: 584, 585, fig. 155

Coenograptus gracilis T. S. Hall. Geol. Mag. n. s. Dec. 4, 1899. 6: 445

Coenograptus gracilis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.528

Coenograptus gracilis Ruedemann. N. Y. State Mus. Bul. 52. 1902. p.583, fig. 13

Coenograptus gracilis Fearnsides. Section C, Belfast. 1902. p.1

Coenograptus gracilis Clark. Geol. Mag. Ser. 4, v. 9. 1902. p.498

Coenograptus gracilis Weller. Geol. Sur. N. J. Pal. 1902. 3: 53

Nemagraptus gracilis Elles & Wood. Monogr. Brit. Grapt. pt 3. 1903. p.127; pl. 19, fig. 1a–f

Description. Rhabdosome consisting of two narrow (.2–.6 mm) principal branches which are bent in a sigmoid curve, and attain a length of 60+ mm; and of numerous (as many as 18 on either side) secondary branches, which are arranged in regular series on opposite sides of the main branches near the center of the colony, are gently curved, in their general direction conforming to the curvature of the main branches, frequently quite flaccid and attaining great length (110 mm and more). They begin at a distance of 1 mm from the sicula, and are, in the typical specimens from 1.4–2 mm apart; each arising opposite the aperture of a theca. They increase in width from .4 mm (in lateral aspect) to .8 mm. The sicula is small (1 mm), though conspicuous owing to its position in the center of the rhabdosome; but most frequently placed vertically in the shale and hence

very rarely observable. The first theca originates near the middle of the sicula and the second theca close to the budding point of the first, both thecae growing in opposite directions. They are furnished with apertural mucros. The thecae are long and slender; their length is five to six times as great as their width; those of the main stipes number only six to seven in 10 mm on account of the small overlap of the thecae (one fifth of length); those of the secondary branches number seven to nine in the same space, with an overlap of nearly one third their length and an inclination of

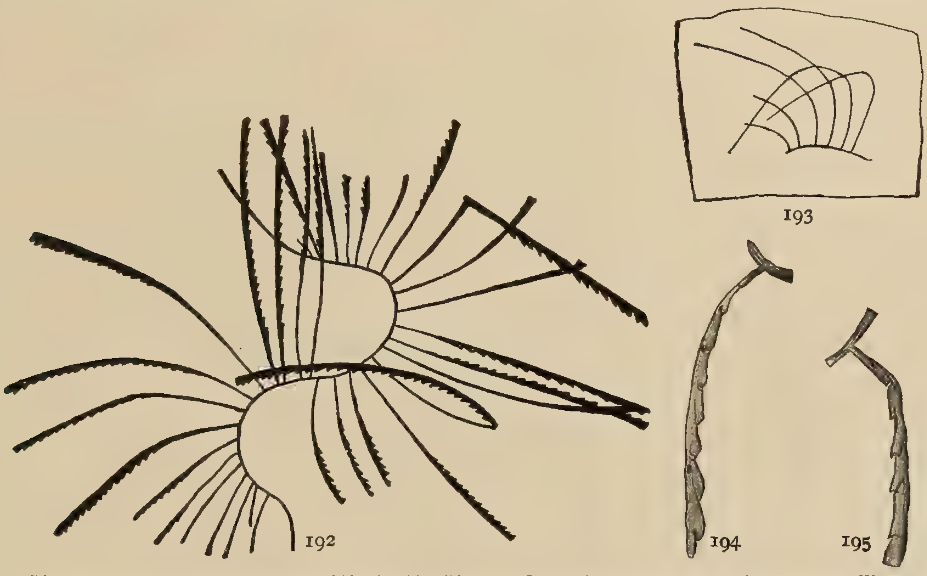


Fig. 192–95 Nemagraptus gracilis (Hall). Fig. 192 Copy of one of Hall's original figures. Fig. 193 Copy of Emmons's figure of "Nemagrapsus elegans." Fig. 194, 195 Enlargements (x 5) of portions of a specimen from the Normanskill

15° in the secondary branches. The outer margins are straight; the aperture is slightly introverted. A nema has not been observed.

Position and localities. Hall described the species from the shales at the Normanskill (Kenwood). It is one of the most typical, though not of the most common forms of this horizon in New York State. We have before us series of fine specimens from Kenwood, the original locality, Glenmont, Mt Moreno near Hudson, Stockport and fragmentary material from other localities in the slate belt. It has been recorded from the same beds in New Jersey [Weller], Maine [Dodge], Canada [Lapworth and Ami]

and Arkansas [Gurley]. Lapworth considered it the most typical graptolite of this zone in Canada (zone of Coenograptus gracilis), and inferred from his material that it did not enter the following zone ("zone without Coenog. gracilis"). Though Ami later found it in the latter, it is evidently very rare there and thus remains a good index fossil of the Normanskill shale or Dicellograptus zone. In the *Monograph of British Graptolites* it is designated as "one of the commonest fossils wherever the graptolitic facies of the Upper Llandeilo rocks is developed" and stated to occur "in abundance" throughout S. Scotland, "where the central members of the Glenkiln beds occur." It is also cited from many localities in Wales, Shropshire and Ireland and gives its name to a zone in Great Britain that corresponds to our Normanskill shale. It likewise characterizes the corresponding zone in Sweden and is known from Australia.

Remarks. The original mode of growth of this graceful form is difficult to decipher from the flattened shale material. The conception of an S-shaped main stem whose one half is ascending and the other descending produced by the compressed material, is not supported by the appearance of the thecae. Elles and Wood have commented on the fact that the thecae of the main stipes appear sometimes on the inner and sometimes on the outer side of the curve and explained this fact by a slight torsion of the main stem produced at the time of its coming to rest by the presence of the secondary branches.

From a survey of our material we would conclude that originally both main stipes were ascending, forming a rather wide lyre-shaped figure but at the same time did not lie in the same plane but would have formed, if continued sufficiently, a very slender double spiral. The observations supporting this view are the following: The variety surcularis shows the extreme upward growth of the branches in this group and at the same time always exhibits a crossing of the distal parts, that is indicative of their growth in different planes. The longitudinal view of the sicula is hardly ever shown in N. gracilis and the two primary and some of the following thecae as a rule are seen from the dorsal side with the transverse section

or the aperture of the sicula in the center of the rhabdosome, while the succeeding thecae of the main stipes exhibit their profile views. There has, hence, taken place a torsion of both branches near the center and the proximal part seems to have settled first in its natural position, i. e. with the sicula in vertical position. The two main stipes then were turned to opposite sides on account of their opposite spiral growth, which carried them out of the axial plane of the rhabdosome. The secondary branches which were arranged on the outside of the lyre and were also slightly ascending, came thereby to fall on opposite sides of the main stipes. They also show throughout a slight torsion, of either primary or secondary origin, for their basal parts are nearly always shown in dorsal or ventral views and the remainder in lateral view [*see* Hall's fig. 6]. It is evident that the mode of arrangement of the secondary branches here inferred would produce an equal and equidistant distribution of the same on the surface of a conical body and thereby prevent their crowding or mutual interference.

The writer has in a former publication [1902, p.583] figured a specimen showing the composition of the main stipe of thecae. At the same place it has been demonstrated that there exist certain differences between the thecae of the main stipes and those of the secondary branches in Goniogr. thureaui and the terms "stolonal" and "brachial" thecae have been proposed for these different thecal expressions. The figures of the arrangement of the thecae given in the description of N. gracilis, show at once that also in this species there exist differences between the stolonal and brachial thecae. The principal one seems to lie in the amount of overlap, those of the main stipes being merely in contact and those of the secondary branches overlapping about one third their length.

Another important difference between the stolonal and brachial thecae is to be seen in the fact that each stolonal theca has the power to throw off two thecae,— one close to its own budding point which diverging becomes the first theca of a secondary branch, and another one near its aperture in the direction of the main stipe,— while those of the secondary branches only produce one theca each of their own category. Further, the thecae of

the main stipes are relatively wider than the earlier thecae of the secondary branches and above all possess a thicker periderm than any thecae of the lateral branches. The result of this last mentioned difference is a marked contrast in the preservation of the main stipes and lateral branches in most of our specimens, the former being little compressed and glossy, the latter flattened out completely and very frequently so thinned that the thecal form is obscured. The dorsal wall of the main stipes seems to have possessed an especially thick periderm and thereby functioned as a support for the branches, exactly as in Tetragraptus amii (described in Memoir 7, page 536).

In well preserved specimens, as that reproduced in plate 16, figure 1, it can be seen that the distal parts of the main stipes possess in their thecae the properties of the secondary branches. A number of thecae beyond the last point of budding of a secondary branch, have, however, the small overlap and thicker periderm of the stolonal thecae and belong clearly to the latter class, although they have not yet thrown off secondary branches. They undoubtedly will do so in the further growth of the colony.

In the amount of introversion of the apertural parts, there does not seem to exist any appreciable difference between the stolonal and brachial thecae.

Nemagraptus gracilis var. **surcularis** (Hall)

Plate 17, figures 1, 2

Graptolithus gracilis (part) Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p 56, fig. 1–4

Graptolithus gracilis (part) Hall. Can. Org. Rem. Dec. 2. 1865. p.13, fig. 12–15

Coenograptus surcularis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p. 179, fig. 13–16

Coenograptus surcularis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. Rev. ed. 1870. p.211, fig. 13–16

Coenograptus surcularis Lapworth. Cat. West. Scott. Foss. 1876. pl. 3, fig. 64

Coenograptus surcularis Lapworth. Belfast Nat. Field Club. Rep't & Proc. 1877. p.143, pl. 7, fig. 12

cf. Pterograptus dilaceratus Herrmann. Nyt Mag. f. Naturvidensk. 1885. 27: 190, fig. 7

Stephanograptus surcularis Walcott. Geol. Soc. Am. Bul. 1890. 10: 338

Stephanograptus surcularis Gurley. Jour. Geol. 1896. 4: 296

Nemagraptus gracilis var. surcularis Elles & Wood. Monogr. Brit. Grapt. pt 3. 1903. p.129, pl. 19, fig. 2a–d

Hall has figured a series of specimens in the above cited publications [*see* text fig. 196] as growth stages of N. gracilis, but becoming doubtful [1868, p.179] of their ontogenetic relation to that species, suggested surcularis as an appropriate name for them. This species has been recognized by Lapworth and listed by Gurley [1896] as a separate species, but in the *Monograph of British Graptolites* reduced to a variety of N. gracilis. It is stated there: "It was regarded by Hall as a young form of N. gracilis, but if so the direction of the stipes must have been modified at a later stage of growth of the species, for no large form preserving the aspect of var. surcularis has as yet been found on either side of the Atlantic, although small forms of the type of N. gracilis are not uncommon. We can only consider that they are the same form if we imagine that in the later stages of growth one branch underwent torsion. There appears to be a certain amount of evidence for this view, but it is too small to justify the inclusion of the two under one name."

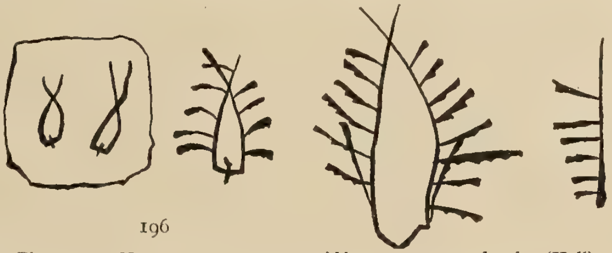

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Fig. 196–97 Nemagraptus gracilis var. surcularis (Hall). Fig. 196 Copies of Hall's original figures. Fig. 197 Enlargement (x 5) of the proximal portion of a specimen from Stockport, N. Y. (Original in National Museum)

We have found this type to be quite common in a layer of the Normanskill shale at Glenmont. Here it forms extremely intricate masses, which have a certain rigid habitus in common that suggests at once a differentiation from the more flaccid, drifted masses of N. gracilis, but on closer examination it is found that these patches while in the majority composed of the γ-like rhabdosomes of surcularis, also contain flat S-like rhabdosomes which in no other characters differ from the typical

surcularis. The inference to be drawn from these occurrences is that the differences of mode of growth between the two were smaller than the flattened specimens would suggest, both having grown in upwardly directed double spirals [*see* under N. gracilis, p. 280]. In surcularis, however, the main stipes formed a smaller axillary angle, were less curved and more directly ascending, while in N. gracilis they were separated wider at the base, had a greater curvature and diverged further from the axillary plane of the rhabdosome. As a result of this the two stems in N. gracilis were always, in becoming compressed, thrown to opposite sides and the sigmoid curve produced, while in the variety surcularis they were both turned to one side and became crossed, producing a *r*-like figure.

The sicula [fig. 197] has in this variety the same dimensions as in the type species and is equally conspicuous; besides it bears a long thin sicular spine (virgella ?) and shows frequently a distinct nema. The two primary thecae are horizontal and provided with small mucros, but the next thecae grow already upwards. The main stipes attain but a small length (about 10–17 mm) and small width (.3 mm). The secondary branches are almost straight, seem not to number more than eight on either main stipe, are about 7.5 mm long and but .4 mm to .5 mm wide; the component thecae are closely arranged and number 10 to 12 in the space of 10 mm.

The figures here given indicate that surcularis is closer related to the variety of N. gracilis here distinguished as N. gracilis var. approximatus, than to the typical N. gracilis. The two varieties have above all the close arrangement of the thecae and of the secondary branches in common and as a corollary they also differ from the typical gracilis by a greater rigidity of the branches, thereby assuming a somewhat different habit.

Position and localities. Hall obtained his material at the Normanskill (Kenwood); besides this we have before us specimens from Glenmont, N. Y. associated with N. gracilis, Diplogr. foliaceus, Climacogr. bicornis, Dicranogr. furcatus, Dicranogr. ramosus;

and from Stockport, where it is found with Dicellogr. sextans and Clathrogr. geinitzianus.

In Great Britain it is "a comparatively common form in the Glenkiln shales of S. Scotland" and it also occurs in N. Ireland.

Nemagraptus gracilis var. crassicaulis Gurley

Plate 17, figure 13

Stephanograptus crassicaulis Gurley. Jour. Geol. 1896. 4: 68

The original description of this species is:

Specimen resembling one half of S. gracilis but with a much thicker curved main stem and branches, the former measuring from 0.50 to 0.75 mm in thickness, the latter in the distal portions attaining a width of 1 mm. The branches are given off from the main stem at first at a right angle, but with each succeeding branch the divergence becomes less. The thecae on the distal portion of the branches measure 20 in 25 mm.

Horizon and locality. Lower *Dicellograpsus* zone, Stockport, N. Y.

This species differs from all others of the genus in its very stout polypary. Though only one half of the polypary has been seen, the generic reference seems hardly open to doubt so much does the habit of the species resemble that of S. gracilis.

Since Gurley has not published any figures, we insert here two [text fig. 198], which accompanied his manuscript and were approved by him. These are to be considered as the type figures of the variety. We also add two further figures of the same material to illustrate features not brought out by the original drawings.

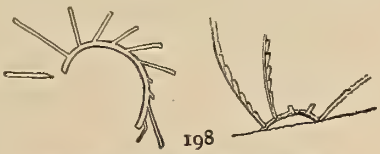

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Fig. 198, 199 Nemagraptus gracilis var. crassicaulis Gurley. Fig. 198 Gurley's original drawings. Fig. 199 Enlargement (x 5) of portion of one of Gurley's types (Originals in National Museum)

We have not found any other specimens of this remarkably robust form, but would supplement the original description by the following data taken from the type and a cotype (the only two specimens known): The sicula and primary thecae are not exposed. The main stem has a width of .6 mm; the secondary branches one of .4 mm to 1 mm. They are 1 to 2 mm apart at their bases and the thecae of the secondary branches number from six to eight in 10 mm. They overlap about one third their length; their inclina-

tion is 10° and they are about four times as long as wide. Their ventral free walls are approximately straight; the apertural parts slightly introverted.

It will be seen from these data, that the characters of this form are essentially those of a N. gracilis but that the branches are more robust owing to greater thickness of the periderm and greater width of the thecae. As Gurley has pointed out, the habit of this form resembles that of N. gracilis; this observation and the like arrangement and length of the thecae suggest that crassicaulis is but a variety of N. gracilis. More complete material, however, will have to be obtained to clear its relationship.

Nemagraptus gracilis var. distans nov.

Plate 16, figures 7, 8

A few specimens from a bed at Glenmont exhibit certain extremes of the characters of N. gracilis which while apparently barely sufficient for varietal distinction, yet indicate a clear tendency to differentiation in a certain direction. A characteristic specimen of this group is that reproduced in plate 16, figure 7. Its branches are more slender and flaccid than in the typical specimens and in conformance with this character, the thecae are more loosely arranged, there being counted but seven in 10 mm on the secondary branches and five in the same space on the main stipes. There is also developed a smaller number of secondary branches in specimens that approach maturity, as in the above mentioned example which has but five on one side and six on the other, although they have already attained a length of more than 40 mm.

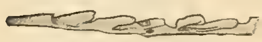

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Fig. 200, 201 Nemagraptus gracilis var. approximatus nov. Enlargements (x 5) of portions of branches of the two types of the variety

This type is mainly conspicuous by the longer intervals between the bases of the secondary branches, and the smaller number of the latter. Its extreme development is represented in plate 16, figure 8. In the original of this figure the stolonal thecae are more than 2 mm long and the main stipes and branches exceptionally thin (but .2 mm wide).

Nemagraptus gracilis var. approximatus nov.

Plate 16, figures 5, 6

We have above distinguished a variety of N. gracilis as var. distans which goes beyond the extreme of looseness in arrangement of thecae and reduction of number of secondary branches, properly considered as diagnostic of N. gracilis.

The present form is a perfect pendant to that variety; it varies in the same characters but in opposite direction and represents a tendency to closer arrangement of thecae and production of more lateral branches than the typical gracilis possesses. While the latter has but 7 to 9 thecae in 10 mm, this has 10 to 12 in the same space of the secondary branches, and the latter are but 1 mm apart (10 stolonal thecae in 10 mm, against 6 to 7 in typical gracilis). The overlap of the brachial thecae is correspondingly greater and reaches one half the length of the thecae, while the outer margin is slightly more convex and the apertural part also more distinctly introverted [*see* pl. 16, fig. 6 and text fig. 200, 201].

The close arrangement of the thecae of the secondary branches and the small intervals between the bases of the latter will serve to distinguish this variety from other conspecific forms.

This variety occurs at Glenmont (in association with Dicellogr. sextans) and at the Normanskill (Kenwood).

Nemagraptus exilis (Lapworth)

Plate 17, figures 3-9

Coenograptus exilis, Lapworth. Ms Rep't of 1890

Stephanograptus exilis (Lapworth) Gurley. Jour. Geol. 1896. 4:68

Lapworth's original description, as published by Gurley [*loc. cit.*] with slight alterations, is:

Polypary bilaterally symmetric, consisting of two simple (or compound) monoprionidian branches about 40 mm long; diverging in opposite directions from the center of a minute radicular bar; branches bearing thecae of type of those of S. gracilis Hall. Width of branches at origin about 0.17 mm, proceeding outward at first horizontally (180°), the deflection

increasing, however, at end of first theca to 240°; branches combined in a gentle, flexuous curve to their extremities, averaging in width about 0.5 mm. Thecae 30 or 32 in 25 mm; adnate to the coenosarcal canal, with straight or very slightly convex margins and slightly inclined apertural edge.

The affinities of this form are distinctly with S. pertenuis Lapworth and its associates, S. explanatus and S. nitidulus. From all these, however, it differs in absence of secondary branches and in general form of polypary.

Horizon and locality. Lower Dicellograptus zone, Stockport, N. Y.

Gurley remarks:

To the above description I may add that some specimens indicate that the primary branches give origin to secondary ones, probably from the athecaphorous margin.

No figures of this species have thus far been published; nor were any found accompanying Gurley's manuscript. I therefore insert here drawings of those specimens which were found in the Stockport collection and labeled as Stephanograptus exilis as the original figures of the species. One of these [pl. 17, fig. 4] shows the proximal parts of the secondary branches and having been marked for illustration is evidently the specimen to which Gurley had reference in the before-quoted note. Another specimen from Stockport [pl. 17, fig. 7], which apparently had been overlooked by Gurley, retains the secondary branches to a considerable length on both sides.


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Fig. 202, 203 Nemagraptus exilis (Lapworth). Fig. 202 Enlargement (x 5) of the type. Fig. 203 Proximal part of another specimen from Stockport, also x 5

Much more complete material of this interesting form has been furnished us by the shales at Glenmont [*see* pl. 17, fig. 3, 5, 9]. This, as well as some of the Stockport material, suggests the following supplementary notes:

The main stipes describe, in the compressed state, a flat S-shaped curve like those of N. gracilis, one half being ascending and the other descending and the secondary branches being turned to opposite sides; the latter begin at a distance of no less than 4 mm from the sicula, but are mostly found in much greater distance (twice and thrice that mentioned); they are 1.5 to 2 mm apart and attain considerable length (45+ mm), but are very flaccid in appearance. There have been counted five to eight of them on either side (in one case [pl. 17, fig. 7] apparently 12). They attain a width of .4 mm. The sicula is very conspicuous on account of the absence of branches near the center, and nearly always observable, though but 1 mm long. It is furnished with a long rigid apertural spine. The two primary thecae originate near the middle of the sicula and diverge a little farther down in horizontal direction. They bear distinct, curved spines near the aperture. The following thecae (stolonal or stem thecae) are slender, overlapping but one fifth their length and number 5 to 8 in 10 mm, while those of the branches overlap one fourth and number 8 to 10 in 10 mm. They are about five times as long as wide, their outer margin is gently convex and the apertural part slightly, but distinctly introverted.

From the habit of the complete Glenmont specimens and the dimensions of the branches, the sicula and thecae we have little doubt but that this form should be properly regarded as a variety of N. gracilis and that it is nearer related to the var. remotus than to any other type of Nemagraptus. In fact, we had identified our material with that variety until we found that Gurley had designated like specimens as Stephanograptus exilis. It would seem that our variety agrees fully with that British Glenkiln form in the curvature of the main stipes and the character and dimensions of the thecae, but grows to greater size and develops more secondary branches. An apertural spine of the sicula is not mentioned of N. remotus in the *Monograph of British Graptolites*, but since we have observed it in N. gracilis var. surcularis as well as in numerous specimens of exilis, we infer that it is a common feature of several varieties, not well shown in the British specimens.

At Stockport the variety is associated with N. gracilis, Dicranogr. furcatus, Climacogr. parvus and Diplogr. foliaceus; at Glenmont with Dicellogr. sextans, Dicranogr. ramosus and Climacogr. bicornis.

Nemagraptus exilis (Lapworth) var. **linearis** nov.

Plate 17, figures 10–12

Description. Rhabdosome consisting of two main stipes and a small number of secondary branches at the distal ends of the former. The main stipes are nearly straight, attain a length of 40+ mm and diverge in the compressed material at an angle that varies between 240° and 280°, but most frequently and typically is about 270°. Their width is about .15 mm at the center and has not been seen to increase beyond .3 mm, the stems appearing as uniformly thin lines. The length of the secondary branches is not known, their width is not greater than that of the main stipes and they are but 1.2 mm apart. The sicula is 1 mm long, very conspicuous by its position, and furnished with a straight apertural spine. The primary thecae originate about one third from the apex of the sicula and diverge from it near its center, assuming opposite, horizontal directions. They bear spines just below their apertures. The upward flexure of the main stems takes place on either side with the succeeding theca. The thecae are very slender, six times as long as wide, overlap but very little (about 1/5 their length), have a small angle of inclination (10°) and number 7 to 9 in 10 mm in the main stipes and 8 to 10 in the secondary branches. The apertural parts are slightly introverted.

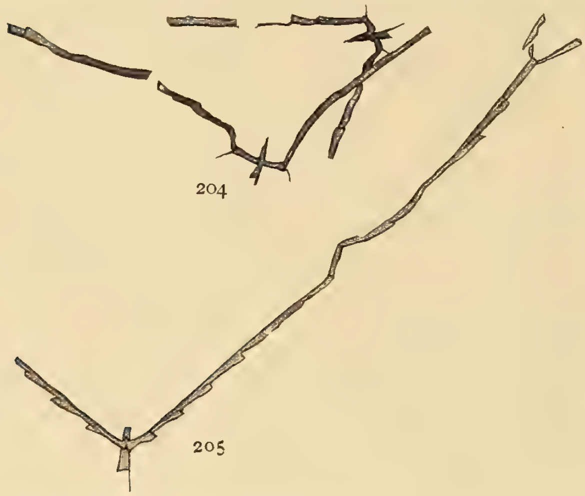

Fig. 204, 205 Nemagraptus exilis var. linearis nov. Enlargements (x 5) of types [pl. 17, f. 12]

Position and localities. This species is most common in one layer

of the Normanskill shale of Mt Moreno, where it is associated with Climacogr. parvus. It is also of frequent occurrence in the shale at Speigletown, Rensselaer co., N. Y. and has been observed in a few specimens at Kenwood and in the collection from Stockport. At Kenwood it is associated with Diplogr. foliaceus, Climacogr. parvus, Dicranogr. ramosus and Dicellogr. mensurans; at Stockport with Climacogr. parvus and Dicellogr. sextans.

Remarks. One could take the representatives of this type for the central parts of rhabdosomes of N. exilis, whose secondary branches had been stripped off during their sinking to the bottom and I have no doubt that the Stockport specimens have been included by Dr Gurley in N. exilis. The sicula and the proximal parts are nearly identical with those of N. exilis and the main stipes similarly thin. But the numerous specimens occurring together at Mt Moreno [*see* pl. 17, fig. 12] leave no doubt that this form differs in constant characters from the similar N. exilis. The principal ones are the greater and more uniform thinness of the main stipes and branches, the different angle of divergence and the nearly straight form of the main stipes. These characters combine to give the variety a habit quite different from that of the typical species.

Family DICRANOGRAPTIDAE Lapworth

DICELLOGRAPTUS Hopkinson

The forms for which Hopkinson erected the genus Dicellograptus in 1871 had before been united with Didymograptus until, when the fact of their different thecal form was recognized by Hall, they were brought under Dicranograptus. From the last named genus they differ in the absence of the biserial portion of the rhabdosome. On this basis the genus is characterized by the diverging of the two uniserial stipes or branches of the first order directly from the sicula and the Dicranograptid type of the thecae.

It is one of the most important genera of the Trenton shales of North America — there are no less than 17 species and varieties of this group described in this paper — indeed, it is so characteristic of these shales that

they have been distinguished into the upper and lower Dicellograptus zones. It is equally well represented in the British Lower Siluric (Ordovician) beds and has been elaborately described in the *Monograph of British Graptolites.*

As its most important characters we have to consider the composition of the rhabdosome of two separate main stipes which embrace an angle exceeding 180° and the introversion and final introtortion of the thecal apertures with concomitant excavation of the ventral walls of the succeeding thecae. These characters are seen in successive stages of development in different species and therefore lend themselves readily to the distinction of subgeneric groups.

Since the angle of divergence of the stipes is greater than 180°, the sicula is found inclosed in the smaller angle formed by the dorsal walls of the stipes. This angle, which is here of especial diagnostic importance, has been termed the *axillary angle* by Hopkinson and the space included between the dorsal walls of the stipes is denominated the *axil* in the *Monograph of British Graptolites.* The form of the latter is variable and of some phylogenetic importance [*see* D. smithi and p. 109].

The proximal end of the rhabdosome is described as possessing two alternate crossing canals, the same as Leptograptus, and an alternate development of the four primary thecae. Our material unfortunately did not contain any reverse aspects of proximal portions that were distinct enough to show the two crossing canals. Two well preserved obverse views are seen in figures 206 and 224. They show the point of origin of the first theca, the horizontal direction of the first two thecae and their mesial spines (the apertures being turned upward into the ventral excavation of the next theca) and the more or less abrupt turning upward of the distal portions of the third and fourth thecae, whereby the stipes are given an ascending direction.

Fig. 206 Dicellograptus gurleyi Lapworth. Proximal portion x 7

The form of the thecae, which finds its most distinct expression in the profile view in the direction of the ventral wall and of the aperture is, as

we have stated before, of phylogenetic importance and expressive of the relative development of the species. It has been utilized in the *Monograph of British Graptolites* for the distinction of four minor groups, all of which are represented in our fauna. By adopting this scheme of subdivision, we obtain the following arrangement of our species:

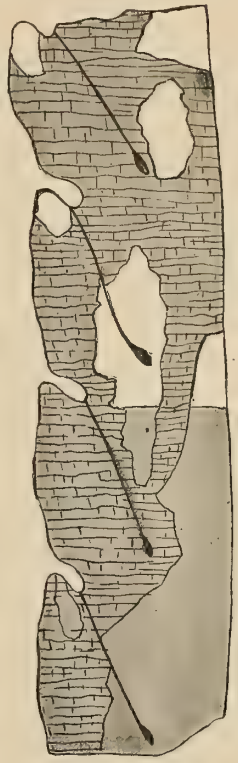

Fig. 207 Dicellograptus anceps Nicholson. Fragment of branch showing simple form of thecae and "pyriform reinforcements" of inner margins of thecal walls. (Copy from Perner)

1 Dicellograpti in which the thecae have straight ventral walls and horizontal apertures.

Type. Dic. complanatus — Dic. complanatus
D. mensurans

2 Dicellograpti in which the thecae have approximately straight ventral walls, but slightly introverted apertural portions.

Type. Dic. divaricatus — Dic. divaricatus
var. bicurvatus
var. salopiensis
var. rigidus
var. rectus
D. intortus

3 Dicellograpti in which the thecae narrow aperturally, have gently curved ventral walls, and slightly introverted apertural portions.

Type. Dic. patulosus — D. gurleyi

4 Dicellograpti in which the thecae have markedly curved ventral walls and strongly introverted and introtorted apertural portions.

Type. Dic. morrisi — D. sextans
var. exilis
var. perexilis
var. tortus
D. moffatensis *var.* alabamensis
D. elegans
D. smithi

Dicellograptus cf. **complanatus** Lapworth

Plate 18, figure 1

Dicellograptus complanatus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5, v. 5. 1880. p.160; pl. 5, fig. 17a–e

Dicellograptus complanatus Tullberg. Sver. Geol. Unders. Afh. och Upps. Ser. C, no. 50. 1882. p.18

Dicellograptus complanatus Roemer & Frech. Lethaea Palaeozoica. 1897. 1: 618, fig. 183

Dicellograptus complanatus Lapworth, Elles & Wood. Monogr. Brit. Grapt. (in Pal. Soc. 1904). p.139; pl. 20, fig. 1a–d

A small series of graptolites collected by Dr Ulrich in dark brown limestone (Sylvan shale), said to lie above the Richmond beds, in the Arbuckle mountains in Indian Territory, contains two proximal parts of rhabdosomes of a Dicellograptus which can not be positively identified since the rhabdosomes are but fragmentary, but which by their habit remind of D. complanatus and of D. forchammeri, especially the former. The rhabdosome possesses the same wide axil, the same angle of divergence (270°), like gently outward curvature of the branches and width of their proximal parts (.5 mm). The sicula is in both specimens incompletely preserved, a peculiarity mentioned also of complanatus; the first thecae are nearly horizontal and bearing short, blunt, lateral spines. Also some of the next thecae are provided with mesial spines. The thecae appear to be, in their characters, entirely like those of D. complanatus. They number 10 in 10 mm, are long and slender (2 mm long), overlapping not quite one half their length, with straight or but slightly convex ventral

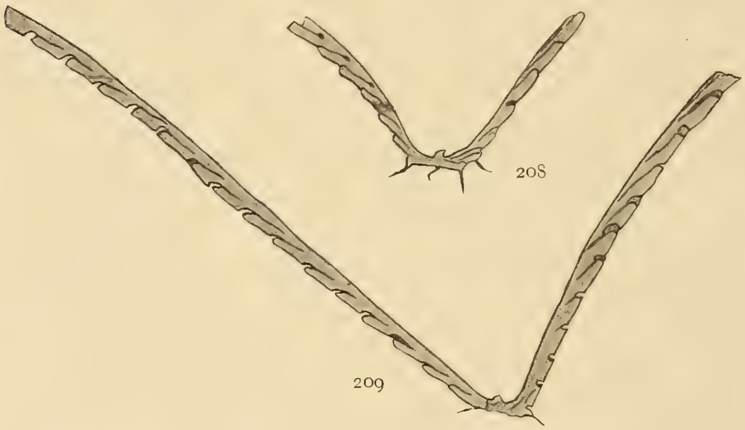

Fig. 208, 209 Dicellograptus cf. complanatus Lapworth. Enlargements (x 5) of two fragmentary rhabdosomes

walls and horizontal, little introverted apertures,[1] lying in rounded, shallow excavations, that occupy about one third the width of the branch and one fifth the length of the free part of the thecae.

D. complanatus is in Great Britain a characteristic graptolite of a zone of the Upper Hartfell shales, occurring in the Moffat and Girvan areas in Scotland and in Ireland; and in Scania it likewise characterizes a zone of the Trinucleus beds. It occurs hence in Europe in beds overlying the zone with Glossogr. quadrimucronatus or beds corresponding to our Utica shale and might be expected in rocks of late Champlainic age in North America.[2]

Dicellograptus mensurans sp. nov.

Plate 18, figure 2

Description. Rhabdosome extremely slender (initial width .2 mm and maximal width but .3 mm); its branches attaining a length of 50+ mm; a short initial part gently concave, so as to form a flat U-shaped axil (angle of this part 240°), then abruptly becoming convex and curved so as to describe more than one half of the outline of an ellipse; the distal ends reapproaching and the whole suggesting a pair of outside calipers but also liable to become irregularly twisted. The sicular extremity is blunt, provided with distinct virgella and two hair-fine lateral spines. Sicula very inconspicuous (1.7 mm long). Thecae numbering 10 in the average in 10 mm with variations to 9 and 12 at the antisicular and sicular ends; long (about 3.6 mm) and narrow, overlapping one half their length, ventral walls straight and subparallel to axis of branch. Aperture slightly introverted, excavation round, its depth a little more than one third of transverse width of branch.

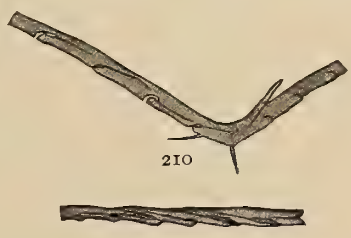

Fig. 210, 211 Dicellograptus mensurans sp. nov. Sicular end and fragment of branch enlarged. x 5

[1] The form of the thecae is shown at the right of the sicular end in text figure 209.

[2] Frech [*loc. cit.*] cites this species also from the Normanskill shale near Albany, probably in error.

Position and localities. From the beds of New York State I have seen but one slab. This bears six individuals and comes from the Normanskill shale at Kenwood. The species is associated with Diplogr. foliaceus, Climacogr. parvus and Nemagr. exilis. A specimen with like characteristic curvature, small width of rhabdosome and form of thecae has been observed in the Trenton shales from Alabama, in association with Diplogr. foliaceus var. alabamensis and Dicellogr. smithi.

Remarks. The only congener of which one could be reminded by the form of this graptolite, is D. elegans Carr., but that species has quite different thecae and greater width of the branches. The thecae of D. mensurans indicate that it is one of the primitive members of the genus and probably the most primitive occurring in the New York beds. It represents here the first of the subdivisions of the Dicellograpti, discerned by Elles and Wood, but differs markedly from the other species of this group by the slenderness of its thecae.

Dicellograptus divaricatus (Hall)

Plate 18, figures 3, 4

Graptolithus divaricatus Hall. Pal. N. Y. 1859. 3:513, p.514, fig. 1–4

Graptolithus divaricatus Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p. 58, fig.

Graptolithus divaricatus Hall. Can. Org. Rem. Dec. 2, 1865. p.14, fig. 19

Graptolithus (Dicranograptus) divaricatus Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.180, fig. 20

Didymograptus divaricatus Nicholson. Ann. & Mag. Nat. Hist. 1868. 5:351; pl. 7, fig. 4

Dicellograptus divaricatus Hopkinson. Geol. Mag. 1871. 8:25; pl. 1, fig. 4

Didymograptus divaricatus Nicholson. Monogr. Brit. Grapt. 1872. p 55, 62, fig.

Dicellograptus divaricatus Hopkinson & Lapworth. Quar. Jour. Geol. Soc. 1875. 31:654; pl. 34, fig. 3a, b

Dicellograptus divaricatus Lapworth. Cat. West. Scott. Foss. 1876. p.5; pl. 4, fig. 86

Dicellograptus moffatensis var. divaricatus Lapworth. Belfast Nat. Field Club. Rep't & Proc. v. 1, pt 4. 1877. apx. p.141, pl. 7, fig. 10

Dicranograptus divaricatus Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.34)

Dicellograptus divaricatus Lapworth. Roy. Soc. Can. Proc. & Trans. v. 5, sec. 4. 1886. p.184

Dichograptus divaricatus ? Whitfield. Amer. Jour. Sci. Ser. 3. 1883. 26: 380

Dicellograptus moffatensis var. divaricatus Ami. Can. Geol. Sur. An. Rep't. v. 3, pt 2. 1889. p.60K, 116K

Dicellograptus divaricatus Walcott. Geol. Soc. Am. Bul. 1890. 1: 339

Dicellograptus divaricatus Gurley. Jour. Geol. 1896. 4: 296

Dicranograptus (Dicellograptus) divaricatus Roemer & Frech. Lethaea Pal. 1897. 1: 618

Dicellograptus *cf.* divaricatus T. S. Hall. Rec. Geol. Sur. N. S. Wales. v. 7, pt 2. 1902. p.3 ; pl. 12, fig. 3 ; pl. 13, fig. 3

Dicellograptus divaricatus Elles & Wood. Monogr. Brit. Grapt. pt 4. 1904. p.143 ; pl. 20, fig. 5a, 5b

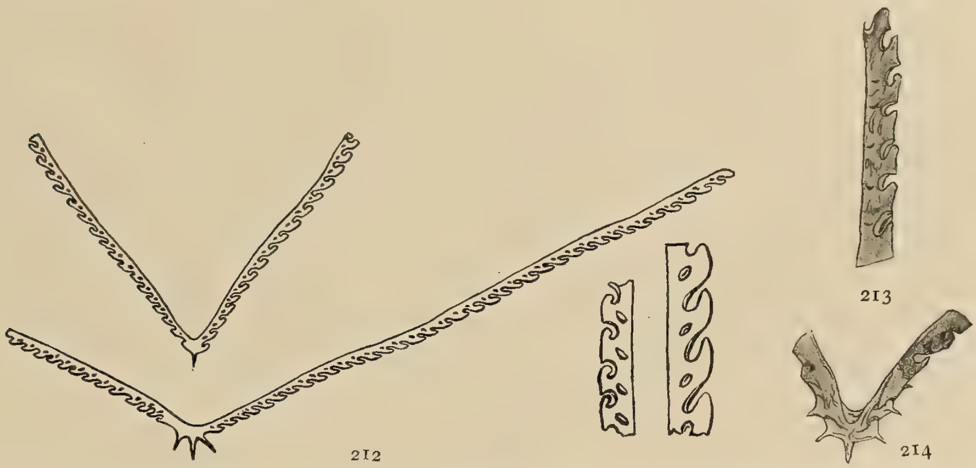

Fig. 212–14 Dicellograptus divaricatus (Hall). Fig. 212 Hall's original figures. Fig. 213 Enlargement (x 5) of portion of branch of the original of the first of Hall's figures. Fig. 214 Enlargement (x 5) of sicular portion of rhabdosome, showing sicula (pressed against branch) and small web. Original in National Museum

Description. Branches of rhabdosome attaining a length of 75 mm or more each, varying between straight and rigid on one hand and curved and flaccid on the other ; the curvature being in some (see varieties) concave in a short proximal part giving to this a V-like shape and abruptly changing to a straight or slightly convex direction ; in the typical form widening rapidly from an initial width of .6 mm within 20 mm to one of 1 mm which is

but little increased, diverging at an angle that varies between 240° and 300°; the axil, as a rule, about 90°, while the distal parts of the branches may become horizontal. Sicula small (about 1.2 mm), with short nema and a thin, straight virgella (.6 mm long). Primary thecae bearing longer lateral spines and first eight or more thecae of each branch short, blunt, mesial mucros. Thecae numbering 9 to 11 in 10 mm; about 1.5 mm long in the mature parts, overlapping one half their length when mature, and less in the initial part; the free outer margin straight and subparallel to the axis of the branch. Aperture introverted, opening into a semicylindric excavation which occupies half the width of the branch and one third the length of the free ventral wall of the theca, leaving an open obliquely recurving notch in the ventral wall.

Position and localities. The original locality of this species is the Normanskill at Kenwood and its horizon the Normanskill shale. It occurs not infrequently in the same horizon at Glenmont and Stockport, but does not seem to be of very common occurrence in any of the localities of the slate belt. It is known to the Canadian geologists from the equivalent shales in Quebec and Gurley has recorded it from homotaxial beds in Arkansas. It, therefore, seems to have had in this country a restricted range. In Great Britain it is also confined to the Glenkiln beds and has been found in South Scotland and Wales and perhaps in Shropshire. In Australia specimens from Stockyard Creek in New South Wales have been, with some doubt, referred to this species.

Remarks. Hall added the figures of two specimens [*see* text fig. 212], to the original description, which widely differ in their angles of divergence, stating that the angle varies between 90° and 120° (240° and 270°). Some of the following observers have regarded these two as representing different species and there exists still at present disagreement as to whether they are conspecific. The monographers of the British graptolites, for instance, concur with Lapworth's former identification in citing the second form alone as representing D. divaricatus, while, on the other hand, Gurley's manuscript contains the following note on this species:

The two forms figured by Professor Hall have been regarded by some as separate species and I held this view until after I had examined a large series for the purpose of defining the supposed two species. I was however unable to find any characters upon which to base a distinction. From the forms represented by Professor Hall's upper figure [fig. 212] characterized by a narrower angle with rigid branches straight from their origin and more rapidly increasing in thickness, to those characterized by a larger angle (which moreover is increased a short distance from the base by the curving of the branches away from each other) and more slender branches, every gradation occurs.

We have not been able to find these gradations in the Stockport material and observing in the collection from Glenmont still more extreme forms [*see* pl. 18, fig. 7], which however preserve a certain uniformity among themselves in different layers, we have deemed it necessary to distinguish these as varieties, the aforegiven description being drawn wide enough to comprise all of them. As the typical form we will consider that selected by Lapworth, Elles and Wood. This [*see* pl. 18, fig. 3] has a large angle of divergence (270° and more) and nearly straight and rapidly widening branches. It is the most common representative of the species at Stockport.

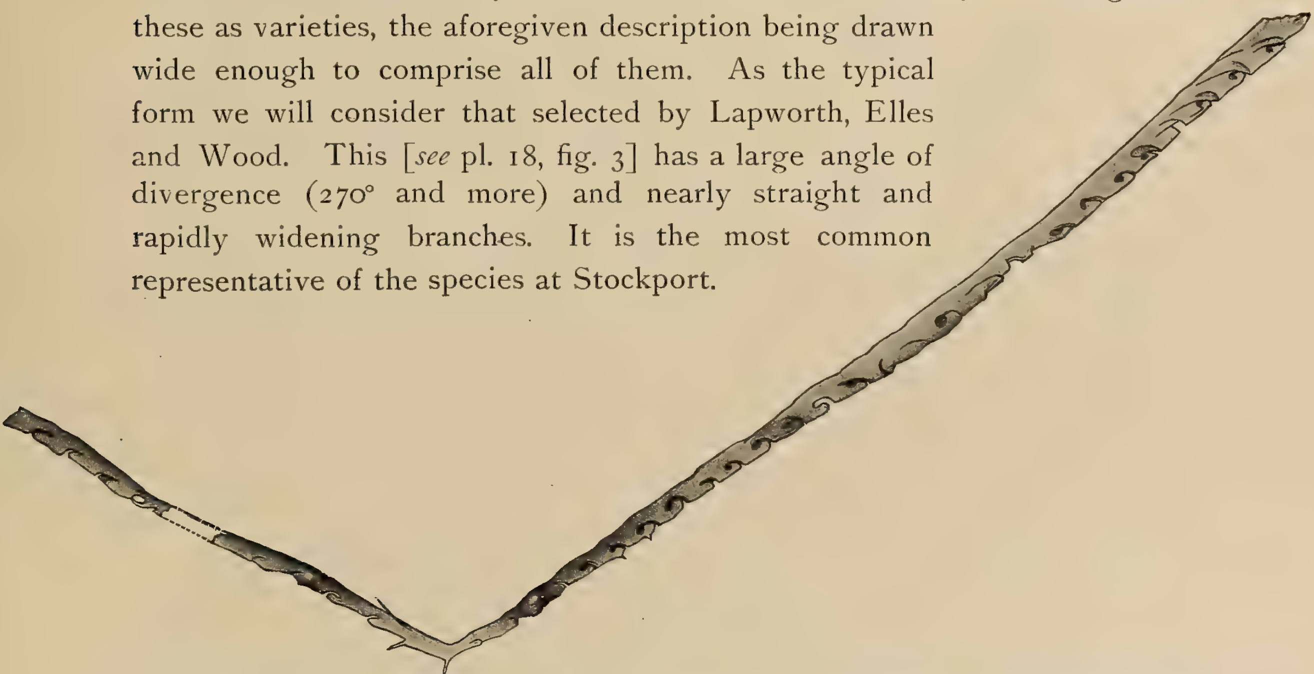

Fig. 215 Dicellograptus divaricatus var. rectus nov. Enlargement (x 5) of original of plate 18, figure 7 (type of variety)

Dicellograptus divaricatus Hall var. **rectus** nov.

Plate 18, figure 7

A distinct variety is that represented by figure 215. This has also straight and steadily widening branches which, however, diverge at a greatly

smaller angle (240° only in this specimen). This form may be distinguished as D. divaricatus var. rectus. It occurs at Kenwood and Speigletown.

Dicellograptus divaricatus Hall var. **bicurvatus** nov.

Plate 18, figure 8

This form possesses slower growing branches, acutely concave axils, and a tendency to bend abruptly, from 2 to 5 mm. from the sicular extremity, into slightly convex, less widely diverging, rather flaccid branches. The thecal apertures appear to be a little more introverted than those of the typical form and the first five to eight thecae of each branch are provided with mesial spines, which are longest at the sicular end and gradually dis-

216

Fig. 216 Dicellograptus divaricatus var. bicurvatus nov. Sicular portion of type of variety [pl. 18, fig. 8] enlarged x 5

217

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Fig. 217–19 Dicellograptus divaricatus var. salopiensis Elles & Wood. Enlargements (x 5) of portions of branches: Figure 217, of proximal portion of original of plate 18, figure 6. Figure 218 of portion of that of plate 18, figure 5; figure 219 of fragment presumably belonging here

appear in distal direction. The V-shaped axil is especially characteristic of this variety, which we propose to name D. divaricatus var. bicurvatus. This form is the most common representative of the species at Glenmont and at the Normanskill.

Dicellograptus divaricatus Hall var. **salopiensis** Elles & Wood

Plate 18, figures 5, 6

Dicellograptus divaricatus var. salopiensis Elles & Wood. Monogr. Brit. Grapt. pt 4 (Pal. Soc. 1904) p.145; pl. 20, fig. 7a–e

Elles and Wood have distinguished a variety as salopiensis which "is characterized by its slender stipes, which have throughout their extent a uniform width of .5 mm only. The thecae are of the same general type as those of D. divaricatus, and number 12 to 10 in 10 mm." It occurs in the Glenkiln beds of Shropshire and of south Scotland. A like variety occurs here in the Normanskill shale at Stockport and Kenwood.

Dicellograptus divaricatus Hall var. **rigidus** Lapworth

Dicellograptus divaricatus Lapworth. Cat. West. Scott. Foss. 1876. pl. 4, fig. 86

Dicellograptus moffatensis var. divaricatus Lapworth. Belfast Nat. Field Club. Rep't & Proc. v. 1, pt 4. 1877. apx. p.141; pl. 7, fig. 10

Dicellograptus divaricatus var. rigidus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5, v. 5. 1880. p.163; pl. 5, fig. 20

Dicellograptus rigidus Gurley. Geol. Sur. Ark. An. Rep't. 1890. 3:416

Dicellograptus rigidus Gurley. Jour. Geol. 1896. 4:297

Dicellograptus divaricatus var. rigidus Elles & Wood. Monogr. Brit. Grapt. (Pal. Soc. 1904.) p.144, fig. 88a; pl. 20, fig. 6a–e

This remarkable variety has been described by Dr Gurley from Arkansas as follows:

This species resembles in angle of divergence and general outlines D. divaricatus Hall, but may be readily distinguished from that species by the great thickness of the branches (about 1.5 mm or 1/16 inch) and especially by the uniformity of the thickness throughout the whole length. This form also differs markedly from Professor Hall's species in character of the base, which is much wider, stouter and more rounded. Hydrothecae about 9 in the space of 10 mm (22 to the inch). The Arkansas form agrees closely with the diagnosis given by Professor Lapworth for his var. rigidus. As he suggests, this form is entirely distinct from D. divaricatus.

Horizon and locality. Dicellograptus zone locality no. 32.

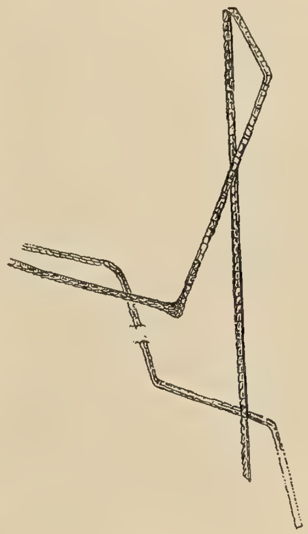

Fig. 220 Dicellograptus divaricatus var. rigidus Lapworth. Rhabdosome from Arkansas. Nat. size

We insert here a drawing of the best Arkansas specimen, made under Dr Gurley's supervision. As in the British variety the sicular part possesses a small peridermal film or "web," extended between the dorsal sides of the branches. This gives to it a thickened appearance. The thecae are not well shown in any of the specimens.

Dicellograptus intortus Lapworth

Plate 18, figures 9, 10

Dicellograptus intortus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5: 161; pl. 5, fig. 19a

Dicellograpsus intortus polythecatus Gurley. Jour. Geol. 1896. 4: 70

Dicellograptus intortus Fearnsides. Section C. Belfast 1902. separate, p.1

Dicellograptus intortus Clark. Geol. Mag. Ser. 4. 1902. 9: 498

Dicellograptus intortus Elles & Wood. Monogr. Brit. Grapt. pt 4. (Pal. Soc. 1904.) p.146, fig. 90a, b; pl. 20, fig. a–f

Dr Gurley has in 1896 listed a form from Stockport as D. intortus polythecatus var. nov., stating that it resembles Lapworth's species in the mode of growth, character of thecae and dimensions of branches, but differs in having more thecae in a certain space (32 in 25 mm), the first six or eight of which bear spines almost as long as the thecae, and the mode of growth of Dicranograptus furcatus. The latter form it is said to resemble somewhat when the proximal portion of the rhabdosome is absent, but D. furcatus has "thicker branches (1 mm as against .6 for the present form), the thecae are much coarser and are *all* provided with strong spines. The loops are also more elongate and narrow."

We have not been able to find either Gurley's types of this variety in the Stockport collection, nor any drawings of the same in his manuscript.

221 222

Fig. 221, 222 Dicellograptus intortus Lapworth. Sicular portions of rhabdosomes, enlarged x 5. Figure 221, that of original of plate 18, figure 9

Several specimens from Stockport (here reproduced in plate 18, figures 9, 10) agree with the description of D. intortus Lapw., given in the *Monograph of British Graptolites*. From this latter description and the excellent figures accompanying it, it appears that the thecae in the British form number from 11 to 14 in 10 mm (28–35 in one inch) and that they also possess spines at the proximal end. This would leave as the only difference the mode of growth, whose validity has been rightly doubted by Gurley himself in his description. It is therefore probable that there cannot be found sufficient differential characters for varietal distinction in the American form.

The specimens here figured show the sicular end whose form, on account of the horizontal growth of the first thecae, is quite characteristic; a long virgella and conspicuous lateral spines but only traces of short spines on the next thecae are seen. The branches are not crossing, possess however a distinct torsion indicating spiral growth. The axillary angle is a little wider than in the typical British specimens.

The species is associated with Diplogr. foliaceus, Climacogr. parvus, Cryptogr. tricornis, Nemagr. gracilis and Dicellogr. sextans var. exilis (no. 23777). We have also found it in the Normanskill shale at Speigletown, north of Troy, in association with Nemagr. gracilis and Dicellogr. sextans.

Dicellograptus gurleyi Lapworth

Plate 19, figures 7-10

Dicellograptus gurleyi Lapworth. Ms Rep't. 1890

Dicellograptus gurleyi Gurley. Jour. Geol. 1896. 4:70

Lapworth states in regard to this species in his manuscript report on the fossils from the Normanskill shale at Stockport, N. Y., that it is "a new and undescribed form belonging to the group typified by D. patulosus Lapw. and intimately allied to D. vagans (Lapworth manuscript, from the Glenkiln beds of Wanlock Head, South Scotland)." He has furnished a careful description of the species which has been published by Gurley, in his preliminary notes on North American graptolites, but the form has not been figured.

The large collection of Normanskill graptolites from Glenmont, probably the best Normanskill collection in number of forms and state of preservation in existence, contains this species in great profusion and in specimens which attain a size greatly surpassing that indicated by the Stockport types. In fact large slabs are so densely covered by the winding branches of this remarkable graptolite that the separate individuals can not be traced in the confused mass. From the Glenmont collection we can materially enlarge the picture of the form drawn by Lapworth. On account of its superior

preservation we have also largely drawn upon it for illustration after careful comparison with Lapworth's type material from Stockport, of which we have also figured the most important forms.

Description. The branches of the rhabdosome grow to a great length, fragments of 175 to 200 mm being quite common; they are characteristically twisted and bent in all possible directions [*see* pl. 19, fig. 8], the proximal part forming a small rectangular axil (first angle of divergence 270°) with

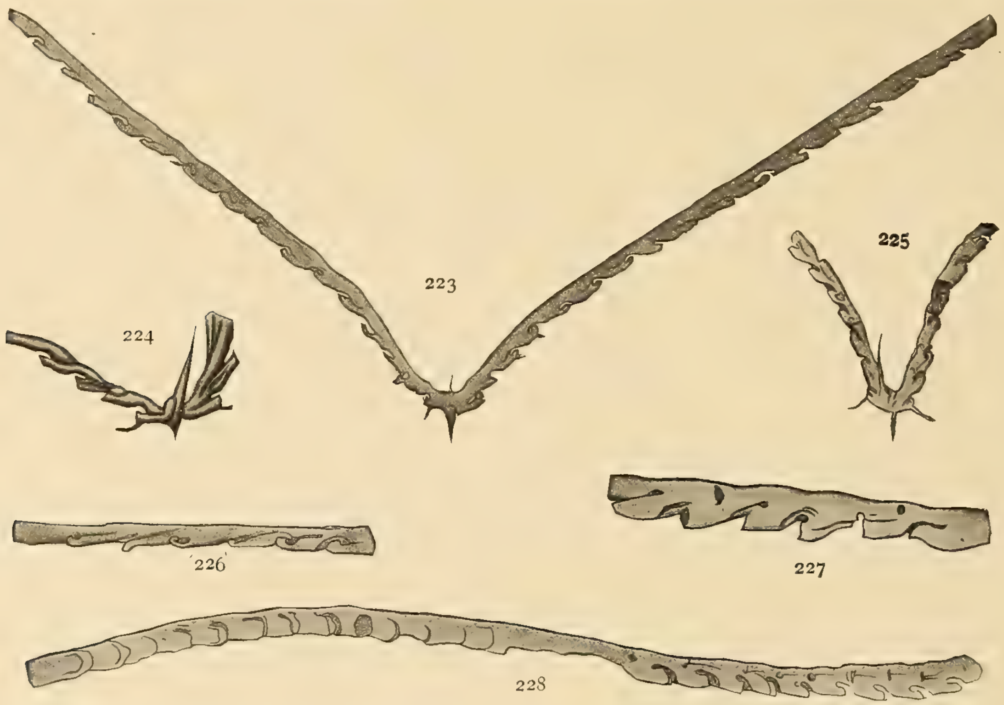

Fig. 223–28 Dicellograptus gurleyi Lapworth. Fig. 223, 226 Lapworth's original manuscript figures (specimens enl. x 6½). Fig. 224 Sicular portion of a pyritized specimen. The draftsman has copied the camera drawing incorrectly, the first thecae connecting in front of the sicula; (obverse view). Fig. 225 Sicular portion with stronger virgella and lateral spines. Fig. 227, 228 Portions of well-preserved mature branches. (x 5.) *See also* text figures 45, 46, 206

slightly concave sides, which as a rule is followed by gently convex curves of the branches. The latter grow in loose, opposite turning spirals and therefore frequently describe the figure 8 and bear the thecae alternately on opposite sides of the branches [*see* "Remarks"]. Branches thin, beginning with a width of .5 mm and soon attaining a uniform width of .7 to .8 mm, which is maintained in the longest branches. Axil wide, the first two

thecae subhorizontal in their direction, provided with short, frequently curved lateral spines. Sicula relatively large (1.6 mm), frequently free within the axil, with short, rigid, rodlike nema and inconspicuous virgella. Thecae numbering 9 to 12 within 10 mm (23–30 in 1 inch), 10 being the average number in the mature branches, overlapping one fourth their length; ventral margin of distal free part slightly convex; apertural part slightly introverted; apertural excavation round, occupying about one third the transverse width of the branch; apertural notch obliquely reflected.

Position and localities. D. gurleyi occurs not infrequently in the Normanskill shale at Stockport, whence Gurley has described it; at Glenmont it is one of the most common, and by reason of its size and numerous flexures and scrolls one of the most conspicuous of the graptolites. It has also been observed in a few specimens at Mt Moreno. Its associates at Glenmont are Diplogr. foliaceus, Climacogr. parvus and Dicranogr. nicholsoni var. diapason.

Remarks. Dr Gurley has suggested in the original description that this is one of a group of species as yet undescribed and differing in size, length and angle of divergence of the branches. From our larger collection it appears that this species is very well distinguished from all of its associates by its twisted, uniformly slender branches; and further that within the species no differences sufficient for varietal distinctions can be established. Lapworth has compared this species to his D. patulosus and Gurley to D. forchammeri. The large Glenmont specimens indicate that the habit of the rhabdosomes resembled that of D. caduceus Lapw., but that the spiral was much looser and wider. From all three mentioned species it differs by the smaller width of its branches and from the last two still specially by the less introverted apertural part of the thecae. From the flaccid variety of D. divaricatus (D. divaricatus var. bicurvatus) which it resembles in the curvature of its proximal parts it can be distinguished by the slower growth and smaller final width of the branches and the different form of the thecae; the latter variety having straighter ventral walls.

Elles and Wood have, from the distinctness of the growth lines in D. caduceus, concluded that its periderm was of considerable thickness and suggested that the twisting of the rhabdosome so characteristic of that species was due " to the stiff and wirelike nature of the polypary caused in part by this thickened chitinous covering." The specimen of D. gurleyi figured on page 105, which retains but the pyritous filling of the somatic cavities, shows that in this species, which possesses a like twisted nature of the branches, the periderm was indeed thick enough to give the branch a regular tubular outline in spite of the double curvatures of the interior thecal cavities.

That in this species, at least, the crossing and recrossing of the branches is due to the growth in a widening spiral is evidenced by two facts, (1) that a branch will in one crossing be superjacent and in the other subjacent and (2) that the thecae in the flattened specimens appear in successive links of the figures described [*see* pl. 19, fig. 7] on opposite sides of the branches, indicating that the branches were not originally twisted in one plane, as they appear now but in several planes or in a spiral.

Dicellograptus sextans (Hall)

Plate 19, figure 1

Graptolithus sextans Hall. Pal. N. Y. 1847. 1:273; pl. 74, fig. 3

Graptolithus sextans Salter. Quar. Jour. Geol. Soc. 1849. 5:17; pl. 1, fig. 10

Diplograptus ? sextans McCoy. Brit. Pal. Foss. 1855. p.9

Graptolithus sextans Carruthers. Siluria. Ed. 4. 1867. p.61, fig. 8

Graptolithus sextans Nicholson. Quar. Jour. Geol. Soc. 1868. 24:134

Didymograptus sextans Nicholson. Ann. & Mag. Nat. Hist. Ser. 4. 1870. 5:356, p.9

Dicranograptus formosus Hopkinson. Geol. Mag. 1870. 7:356; pl. 16, fig. 2

Dicranograptus sextans Hopkinson. Geol. Mag. 1870. 7:356; pl. 16, fig. 1

Dicranograptus sextans Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 3, fig. 78

Dicellograptus sextans Lapworth. Belfast Nat. Field Club. Rep't & Proc. v. 1, pt 4. 1877. Apx. pl. 7, fig. 4

Dicellograptus sextans Linnarsson. Sver. Geol. Unders. Ser. C, no. 31. 1879. p.18f

Dicellograptus sextans Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 6: 19

Dicranograptus sextans Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet 1879. p.34)

Dicellograptus cf. sextans Tullberg. Sver. Geol. Unders. Ser. C, no. 50. 1882. p.20

Dicellograptus sextans Lapworth. Roy. Soc. Can. Trans. v. 5, sec. 4. 1886. p.178

Dicellograptus sextans Ami. Can. Geol. Sur. Rep't. Ser. 2, v. 3, pt 2. 1889. p.117K

Dicellograptus sextans Walcott. Geol. Soc. Am. Bul. 1890. 1: 339

Dicellograptus sextans Gurley. Jour. Geol. 1896. 4: 297

Dicellograptus sextans ? T. S. Hall. Roy. Soc. Victoria. Proc. 1896. 9: 184

Dicranograptus (Dicellograptus) sextans Roemer & Frech. Lethaea Pal. 1897. 1: 621

Dicellograptus sextans T. S. Hall. Geol. Mag. n. s. Dec. 4, v. 6. 1899. p.445

Dicellograptus sextans Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.539

Dicellograptus sextans Clark. Geol. Mag. Ser. 4. 1902. 9: 498

Dicellograptus sextans Fearnsides. Section C. Belfast 1902. Separates, p.1

Dicranograptus sextans Richardson. Terranes of Orange Co., Vt. 1902. p.63

Dicellograptus sextans Elles & Wood. Monogr. Brit. Grapt. pt 4. 1904. p.153; pl. 21, fig. 1a–e

Dicellograptus sextans Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33

Dicellograptus sextans Ami. Geol. Sur. Can. Sum. Rep't. 1905. p.12

Fig. 229, 230 Dicellograptus sextans (Hall). Fig. 229 Enlargement (x 5) of typical specimen. Fig. 230 Enlargement (x 5) of sicula with first thecae

Description. Branches of rhabdosome diverging at 300°, with acute axil; straight in shorter specimens and gently curved in longer ones, sometimes with the ventral side as the concave one, but more frequently with a convex ventral side thereby approaching the shape of the handles of a pair of pliers; mostly about 10 mm long, rarely surpassing 20 mm; usually of uniform width [*see* "Remarks"], which is .8 mm. Sicular extremity broad, slightly rounded, with short virgella and two lateral spines. Sicula inconspicuous (.9 mm long). Nema short and thin. Thecae numbering 11 to 13 in 10 mm, short (1 mm), overlapping one

fourth their length; with obliquely directed strongly convex outer wall, which on its highest mesial part carries a spine; and slightly introverted or introtorted apertural portion, which is inclosed in a semicylindric excavation, occupying one third the width of the rhabdosome.

Position and localities. Hall knew the species only from the black slates at the Normanskill (Kenwood). It has also been obtained in great number and several varieties in the Normanskill shale at Glenmont, N. Y. and Mt Moreno near Hudson and at numerous other localities (as Moordener kill near Castleton, Poesten kill at Troy, neighborhood of Tomhannock, Rensselaer co., Stockport, etc.). It can be considered as one of the common and characteristic graptolites of the Normanskill shale in the slate belt of New York. It is likewise common in the northern extension of this belt through Vermont into Canada where Ami and Lapworth have repeatedly observed it. It has long been known in Great Britain and the monographers cite it as a very abundant fossil from many outcrops of the Glenkiln shales in Wales, Scotland (Moffat and Girvan areas) and Ireland. Linnarsson and Tullberg have recorded it from Sweden (zone of Coenograptus gracilis) and T. S. Hall has recognized it in collections from Victoria, Australia.

Remarks. The characters of the earliest thecae of D. sextans have been elaborated by Elles and Wood and described as follows:

> The earliest thecae, th. 1^1 and th. 1^2, are of considerable size, and unlike the corresponding thecae of most of the other Dicellograpti, only a small fraction of their length assumes a horizontal direction, most of their growth being obliquely upward and outward. The same is also the case with th. 2^1 and th. 2^2, which, however, develop alternately as in other species. Hence the proximal end, owing to this alteration in the direction of growth, approximates (like D. anceps) closely to what may be termed the Diplograptid type.

We figure here [229] the reverse aspect of a nepiastic growth stage which would seem to indicate even a short initial downward growth of one or both of the first thecae, similarly as in the Diplograptidae. The same organism shows the hairlike virgella and the apertural position of the lateral spines, as well as the primitive form of the first thecae.

Dicellograptus sextans var. **exilis** Elles & Wood

Elles and Wood have separated from D. sextans a variety as exilis which agrees with the typical form in all its characters, except that it is far more slender, (being only about half as wide as the true sextans) and is found in the same horizon with the latter. We have like narrow specimens in the collections from Glenmont and Mt Moreno. In these the width remains the same throughout and the spines are longer than in the typical form. The original of Hall's figure 3a, plate 74 [*see* enl. 231] belongs to this group.

On the other hand, a slab from Kenwood in the State Museum has

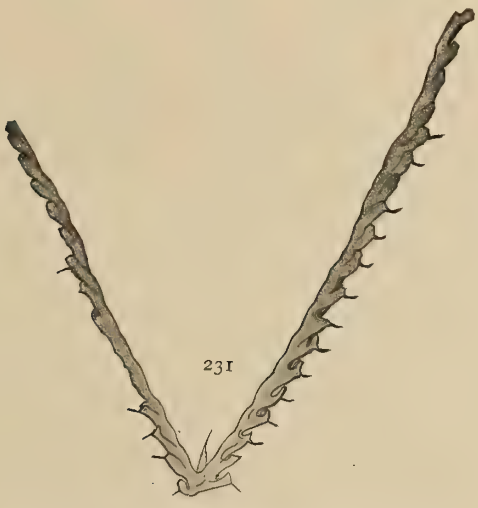

Fig. 231 Dicellograptus sextans var. exilis Elles & Wood. Hall's type of plate 74, figure 3a (vol. 1) x 5

Fig. 232 Dicellograptus sextans var. tortus nov. Obverse view. x 5

been found to be covered with specimens showing an opposite rend of development [*see* fig. 232]. In this variety, which we will designate as D. sextans var. tortus, the branches begin narrow and attain rapidly the maximal width of the true sextans or one still slightly greater. The spines are reduced to blunt mucros. The peculiarly braided appearance of the branches is due to the fact that they are seen obliquely and exhibit the greater part of the dorsal side, where a row of circular pits indicates the budding points of the thecae. This state of preservation is evi-

dently caused by a slight torsion of the branches, which probably is the main differential character of the variety.

Dicellograptus sextans var. **perexilis** nov.

Plate 19, figure 2

Cf. Dicellograptus sextans var. tenuibrachiatus Lapw. Roy. Soc. Can. Trans. 1887. 4:179

In a layer of the Normanskill shale at Mt Moreno D. sextans is represented by a variety, the most striking feature of which is the extreme thinness of its branches, the width of the latter amounting to no more than .2 mm. Besides, the angle of divergence of the branches is constantly smaller (270° in the proximal part and 240° ultimately) and the branches are more flexible. As a result of these characters the habit of the variety is entirely different from that of the typical sextans, but the form and arrangement of the thecae and the presence of mesial spines on all thecae place it with that species.

Fig. 233 Dicellograptus sextans var. perexilis nov. Typical specimen. x 5

From the narrow variety exilis this one is distinguished by its still smaller width (but half that of exilis) and the smaller angle of divergence.

D. sextans var. perexilis is associated with Didymogr. sagitticaulis, Nemagr. gracilis, and Lasiogr. mucronatus.

Dicellograptus moffatensis (Carruthers) var. **alabamensis** nov.

Plate 20, figures 1, 2

Didymograptus moffatensis Carruthers. Roy. Soc. Edinburgh Proc. v. 1, pt 2. 1858. p.469, fig. 3

Dicellograptus moffatensis Elles & Wood. Monogr. Brit. Grapt. pt 4 (Pal. Soc. 1904) p.157 ; pl. 23, fig. 1a–f

Description. Branches of rhabdosome, as a rule, markedly straight,

sometimes gently convex in the distal parts and frequently slightly concave in the sicular region; attaining a length of 70+ mm, increasing from an initial width of .5 mm very gradually to one of .9 mm to 1 mm and hence apparently of uniform width; diverging at an angle of 325° to 330°. Sicular extremity rounded, with short, blunt virgella and lateral spines; short mesial spines continuing to the fourth or fifth theca on either side. Sicula not observed. Four primary thecae develop alternately and instead of growing horizontally outward as in most Dicellograpti, they grow obliquely upward and outward thereby producing a short biserial portion and suggesting a Dicranograptus [*see* under "Remarks"]. The Dicranograptuslike aspect is still increased in some specimens by the acute axil and a "web" which connects the sometimes subparallel dorsal walls of the bases of the branches [*see* fig. 234]. The thecae number quite constantly 10 in 10 mm with but slight variation; the ventral walls of their free parts are strongly convex, at least in the initial part of the rhabdosome; for the thecae of the more distal parts have not been seen in profile in any of the specimens, thereby indicating that the profile line of the thecae did not lie in the intersecting plane of the branches. The apertural parts of the thecae are introverted and opening into pouchlike excavations, which occupy between one third and one half the width of the branch.

234 235

236

Fig. 234–36 Dicellograptus moffatensis var. alabamensis nov. Fig. 234, 235. Sicular portions showing acute axil and "web." Fig. 236. View of mature portion of branch, very unsatisfactory but the best obtainable. x 5

Position and locality. In the upper Trenton shaly limestone near Pratt's Ferry, Bibb co., Ala. where it is the most striking of the graptolites.

Remarks. We consider this form as most nearly related to D. moffatensis Carruthers, which it most approaches in the general form of the rhabdosome and of the thecae, but from which it differs in the expansion of the branches — those of D. moffatensis beginning narrower while expanding more rapidly and to a greater width — and the spinosity of the earliest thecae in our material. The straight and rigid branches of ala-

bamensis assist also in producing a different habit. The axillary angle shows the same variation from an acute to a broader form and the dorsal walls of the branches are joined, as a rule, by a "web" or conchiolinous membrane, as in the British form. In narrow axillary angles this web extends as far as the aperture of the fourth theca of either side; in wider axillary angles, when present altogether [as in text fig. 235], it forms but a narrow crescent band.

Elles and Wood in remarking on the direction of growth of the earliest thecae in D. sextans, state that the "Diplograptid" appearance of the proximal end brings that form into close relationship to the Dicranograpti, so that it might be regarded as one of the intermediate forms between Dicellograptus and Dicranograptus. D. moffatensis var. alabamensis goes still farther in approaching Dicranograptus and quite distinctly points out the path of development of that genus by the approach of the dorsal walls of the bases of the branches and their connection by a web. A further step along this line would be the actual adnation of the two branches and the formation of a septum [*see* p.111].

Dicellograptus elegans Carruthers

Didymograpsus elegans Carruthers. Geol. Mag. 1868. 5: 129; pl. 5, fig. 8a, 8d

Dicellograptus elegans Hopkinson. Geol. Mag. 1871. 8: 24; pl. 1, fig. 3a–e

Dicellograptus elegans Lapworth. Cat. West. Scott. Foss. 1876. pl. 4, fig. 87

Dicellograptus elegans Lapworth. Belfast Nat. Field Club. Rep't & Proc. Apx. 1877. v. 1, pt 4, pl. 7, fig. 8

Dicellograptus elegans Gurley. Geol. Sur. Ark. An. Rep't. (1890). 1892. 3: 414

Dicellograptus elegans Gurley. Jour. Geol. 1896. 4: 71

Dicellograptus elegans Clark. Geol. Mag. Ser. 4. 1902. 9: 498

Dicellograptus elegans T. S. Hall. Rec. Geol. Sur. Victoria. v. 1, pt 4. 1906. p.275, pl. 34, fig. 2

Dr Gurley has cited [1896] this species as occurring at Stockport, N. Y., stating that "specimens occur in our Lower Dicellograptus zone which agree in every respect with Carruthers's species except that they show

24 to 28 thecae in 25 mm, while Carruthers's and also Lapworth's figures show but 20 to 22."

We have not been able to find any specimens in the Stockport collection fitting in to the description of D. elegans lately given by Elles and Wood nor has Lapworth cited the species in his manuscript report on the Stockport fauna; or recognized it in the Normanskill shales of Canada. Since moreover D. elegans is in Europe bound to a younger horizon (zone of Pleurograptus linearis of the Hartfell shales) we believe that some other slender Dicellograptus has been mistaken for this species; and we are probably near the truth in considering D. divaricatus var. bicurvatus as that form; for this has the proximal double curvature, cited by the British monographers as eminently characteristic of D. elegans and also the number of thecae quoted by Gurley. The thecae of D. elegans have strongly curved free ventral walls and their apertural parts are markedly introverted and slightly introtorted, while the variety of D. divaricatus has almost straight ventral walls.

Dicellograptus smithi[1] sp. nov.

Plate 19, figures 3-6

Description. Rhabdosome small (prevailing length of branches almost 13 mm, greatest length observed 22 mm), branches of nearly uniform width, which is .6 mm; first straight and subparallel or including between them a very small axillary angle for about 2 mm, then diverging abruptly so as to include an angle of 60° and becoming concave, thereby converging distally and probably crossing finally. Sicular extremity round, furnished with small virgella and lateral spines. Sicula very inconspicuous, apparently not more than .6 mm long. Thecae numbering 12 to 14 in 10 mm, alternately arranged on the inside and outside of the branches; the first six to seven of either side furnished with small spines, 1.4 mm long; overlapping

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[1] Named after Prof. Eugene A. Smith, State Geologist of Alabama, who has most liberally placed at my disposal the graptolites from the Trenton shales of Alabama and the data on their horizon.

a little more than one third their length; the ventral wall of their free portion strongly convex; the apertural part introverted and introtorted, contained within a semicircular excavation which occupies one half the width of the branch and two fifths the length of the theca.

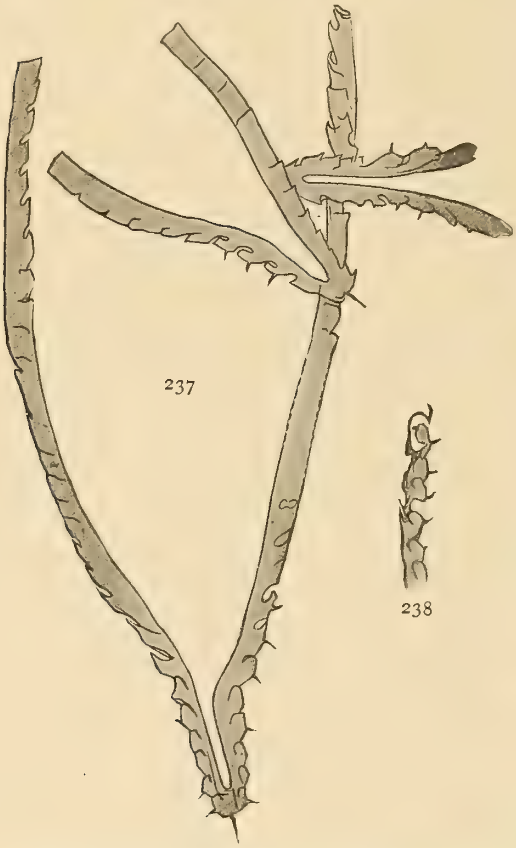

Fig. 237, 238 Dicellograptus smithi sp. nov. Fig. 237 Group of typical specimens. Fig. 238 Portion of branch showing thecae distinctly. x 5

Position and locality. Occurring in great profusion in the upper shaly Trenton limestone near Pratt's Ferry, Bibb co., Ala.

Remarks. The form of the rhabdosome in the compressed condition is varying between wide extremes, which can be but partly due to different directions of compression. While the vast majority of the specimens have the form above described and considered here as the typical expression of the species, a few have been observed to diverge directly at an angle of 270° [*see* fig. 4] and to approach more or less closely to D. sextans in their form, while in others the branches cross already closely to the sicular extremity. This variability can only be taken to mean that the species is in rapid development or transition to another type. Since the form of some of the specimens, as well as the character of the thecae, evince close relationship to D. sextans, while others in the approach of the bases of the branches, which is seen in all stages of evolution, are clearly well on the path to a Dicranograptus, it can be properly surmised that we have here before us a very interesting transitional form from a Dicellograptus of the type of D. sextans to a Dicranograptus of the

group of D. furcatus. We have more fully discussed these transitional characters in the chapter on the phylogeny of the genera, page 109.

The fact, mentioned in the description of this species, of the alternate arrangement of the thecae on the inside and outside of the branches, indicates, together with the convergence of the branches, that the latter grew in a slender spiral, comparable to that of D. furcatus. The not infrequent occurrence of specimens, like those reproduced in plate 19, figures 5 and 6, where the branches cross already close to the sicular extremity, while evidently due to oblique compression, can only be understood if it is assumed that the branches lay from the beginning in different planes.

DICRANOGRAPTUS Hall

Hall separated Dicranograptus first [1865, p. 112] as a subgeneric group from Climacograptus pointing to the similarity of the thecae in Graptolithus ramosus, the type of the new group, and Climacograptus bicornis. In the 20th Museum Report, in the *Synopsis of the Genera of Graptolitidae*, Dicranograptus is given full generic rank but expanded so as to comprise also the present Dicellograptus. The latter having again been separated by Hopkinson, the genus Dicranograptus now embraces all forms which have the characteristic Dicranograptid thecae (with more or less convex ventral walls, apertural introversion and introtortion) and whose rhabdosome consists of a proximal biserial portion and two distal uniserial stipes.

Like Dicellograptus it appears abruptly and attains a sudden dominance in the Trenton shales, where by the number of individuals and still more by the size of its robust rhabdosomes, it is one of the most prominent genera, and disappears again as rapidly in the succeeding formation.

The form of the complete rhabdosome — or eventually synrhabdosome — and its mode of suspension and fixation, as well as the probable origin of the biserial section and the question of the presence of an axis (virgula) have been discussed in the introductory chapters. Also in regard to the phylogenetic relations of the genus we refer the reader to page 109.

The sicula is small and only visible in the obverse aspect. It is seen in figures 239, 248 and 255. In 255 also the virgella and the mesial position of the lateral spines on the first two thecae are distinctly shown. Figures 241, 248, 253, 261 and others serve also to illustrate the mesial position of the spines of the later thecae on the apex of the convex ventral walls [*see* chapter on origin of spines, p.69].

The four primary thecae have an alternate arrangement as in Dicellograptus, but the first and second thecae [*see* fig. 255, 259] grow only a very short distance horizontally outward and bend then directly upward. The later thecae grow in most species in two different series, which for the remainder of the biserial section are coalescent and separated by a septum; the single "common canal" of the primary thecae becomes hence divided into two.

The septum is seen in several of the enlargements [*see* fig. 241]. It is especially distinct in D. nicholsoni where it begins directly above the sicula, while in D. spinifer [*see* fig. 265] the alternate budding of the thecae appears to be continued much longer. Probably incorporated in it is the nema which as figure 41 shows, was of considerable thickness and by which the young rhabdosome was suspended until the time of the separation of the coalescent stipes. It also served as support for the ascending thecae of the biserial section, similarly as in the Diplograptidae.

Emmons has in 1856 described two species as Cladograpsus dissimilaris and inequalis. The former, from an unknown horizon and locality, is figured [pl. 1, fig. 15] and based on a small fragment of a Dicranograptus; the latter, from Parrottsville, Tenn., is only described. Both of these species should be dropped, the first, because its locality is unknown and it can not be determined from the description and figure; the second, probably also a Dicranograptus, because the description is not sufficient for determination.

The British species of Dicranograptus have been arranged in the *Monograph of British Graptolites* by the same principle as those of Dicellograptus, i. e. by the form of the thecae. Only one of the four groups

distinguished, namely the fourth, in which the thecae have strongly curved ventral walls and markedly introverted and introtorted apertures, is represented in our fauna. Its type is D. nicholsoni. The forms here noticed are:

Dicranograptus nicholsoni
var. parvangulus
var. diapason
D. ramosus
var. arkansasensis
D. spinifer
var. geniculatus
D. furcatus
var. exilis
D. contortus

Dicranograptus nicholsoni Hopkinson

Plate 20, figures 3, 4, 5; plate 21, figure 1

Dicranograptus nicholsoni Hopkinson. Geol. Mag. 1870. 7: 357; pl. 16, fig. 3

Dicranograptus nicholsoni Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 3, fig. 79

Dicranograptus nicholsoni Lapworth. Belfast Nat. Field Club. Rep't & Proc. Apx. 1877. v. 1, pt 4, p.141; pl. 7, fig. 2

Dicranograptus nicholsoni Gurley. Jour. Geol. 1896. 4: 297

Dicranograptus nicholsoni Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p.20

Dicranograptus nicholsoni T. S. Hall. Roy. Soc. Victoria Proc. 1905. 18: 24; pl. 6, fig. 7

Non Dicranograptus nicholsoni Roemer & Frech. Lethaea Pal. 1897. 1: 617, fig. 181

Dicranograptus nicholsoni Elles & Wood. Monogr. Brit. Grapt. pt 4 (Pal. Soc. 1904) p.171, pl. 25, fig. 1a–h

Dicranograptus nicholsoni T. S. Hall. Rec. Geol. Sur. Victoria. 1906. v. 1, pt 4, p.274

Description. Rhabdosome consisting of short biserial portion (quite uniformly 5 mm long, with variations to 4 and 6 mm) and long uniserial branches, attaining a length of 130+ mm and forming an axillary angle

that varies from 25° to 80°, probably in consequence of oblique compression, but in the majority of specimens lies between 40° and 60°. The branches are frequently straight, but mostly gently curved, either first concave and then convex, or convex from beginning, so as to reapproach distally. The biserial section begins narrow (initial width .7 mm) but widens to 1.7 mm; the uniserial branches are uniformly 1 mm thick, in some long branches widening gradually to 1.2 mm.

The sicula measures 1 to 1.1 mm, and is furnished with a short virgella. From its apical end a dividing septum proceeds, and only the first four thecae grow alternately. The biserial section consists of 5 to 6 thecae,

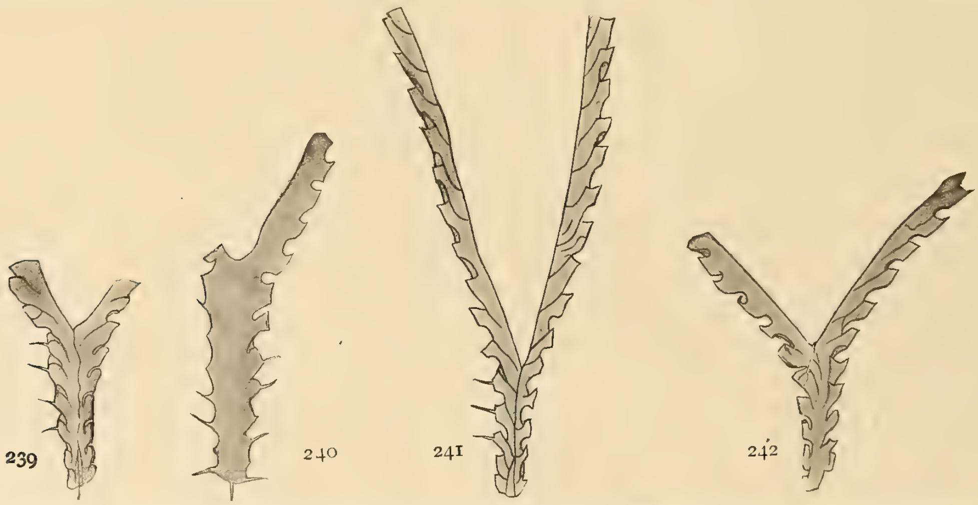

Fig. 239–42 Dicranograptus nicholsoni Hopkinson. Fig. 239 Biserial portion of a rhabdosome showing sicula and septum. From the Utica shale of the Mohawk valley (original in National Museum). Fig. 240 Fragment from the Utica shale of Cincinnati (original in Ulrich collection). Fig. 241, 242 Portions of specimens from the east shore of Saratoga lake. Figure 241 shows distinctly the sicula and septum. Figure 242 shows the profile view of the thecae. x 5

mostly 5, on either side (8 in the Cincinnati specimens). The thecae number mostly 10 in 10 mm (9–13 in 10 mm); they have convex outer walls, which in the biserial section are furnished with strong mesial spines; they overlap about one half their length (the latter, in the later thecae, is 2 mm); their apertural parts are introverted and introtorted and contained in or almost filling round excavations that occupy fully one third or more of the width of the branch.

Position and localities. D. nicholsoni occurs in mutations [*see*

below] already in the Trenton shales; in forms corresponding to the typical nicholsoni of Great Britain it does not appear until Utica time. The National Museum contains slabs with fine specimens, obtained near South Trenton, Oneida co., N. Y., about 6 to 10 inches above the Trenton, according to a note by Dr Gurley. They are there associated with Glossogr. (?) eucharis, Climacogr. typicalis, Triarthrus becki, Leptobolus insignis and Conularia papillata. Some of these specimens have been sent to Professor Lapworth by Dr Gurley and been found by that authority not to differ from the typical form [Gurley 1896, p.72]. Other specimens in the same collection are labeled as coming from the Utica shale of the Mohawk valley. The New York State Museum contains a series of well preserved specimens from a black shale at the east shore of Saratoga lake in Saratoga county, N. Y. The shale occurs in an isolated outcrop and is not yet irrevocably determined as to its age. The presence of Glossogr. (?) eucharis, the only associate of the Dicranograptus in this shale, would, however, also point to its Utica age. Three well preserved fragments of this species have been collected by Dr Ulrich in the "true Utica shale" at Cincinnati, O. (the Dicranogr. ramosus of his list of 1880).

In Great Britain D. nicholsoni is said to be very common, near the top of the Glenkiln shales and in the Lower Hartfell shales, and to be especially abundant and beautifully preserved in the zone of Climacograptus wilsoni. Tullberg has also cited it from the zone with Nemagraptus gracilis in the Middle Graptolite shales of Scania.

Remarks. The careful description and illustration of this species in the *Monograph of British Graptolites* permits a very close comparison of our specimens with the British type material and this furnishes evidence of slight, but constant differences. The most notable of these are the smaller length of the biserial portion (here uniformly 5 mm), its smaller width and the more slender and more convex form of the uniserial branches. Also the axillary angles seem to vary between greater limits and to be somewhat greater in the average. These differences are most uniformly

and strikingly shown in the material from Saratoga lake; but also apparent in the specimens from Oneida county. On the other hand two of the fragments from Cincinnati agree exactly with the description of the British specimen in the length of the biserial section and its rapid widening to the point of separation, while the third has the identical characters of the Saratoga types in the biserial portion, which alone is retained. For this reason we have thought it best to extend the description of D. nicholsoni sufficiently to receive the latter form.

a **Dicranograptus nicholsoni** var. **parvangulus** Gurley

Plate 21, figure 2

Dicranograptus nicholsoni var. parvangulus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:417

Dicranograptus nicholsoni parvangulus Gurley. Jour. Geol. 1896. 4:73

Dr Gurley has twice described, but not figured this well defined variety. We insert here his original (manuscript) drawings and add several other drawings of better preserved specimens from the Normanskill shale at Mt Moreno and Glenmont. In the last cited publication Gurley has drawn the following description of this variety from Stockport specimens:

Proximal portion about 6 mm long; at base 1 mm, and immediately below bifurcation 1.5 mm wide; with eight or nine thecae, each with a short, sharp horizontal spine; branches 1 mm wide, diverging at an angle of 35° or 40° (or thereabouts), often bending very slightly towards one another immediately after the division, thus producing a slightly rounded, bulging appearance. Thecae forming bent tubes, as in D. nicholsoni proper; as nearly as possible 24 in 25 mm; those on the proximal portion and the first few on the branches above the bifurcation spiniferous. On the branches not more than three spiniferous thecae were seen.

Position and localities. It was known to Gurley from the Lower Dicellograptus zone at Stockport, N. Y. and in Arkansas, and his Upper Dicellograptus zone at Magog, Canada. We have also found it as the commonest graptolite in a layer of the Normanskill shale at Mt Moreno and likewise in fine specimens at Glenmont, below Albany. In the former place it is associated with Lasiogr. mucronatus and Diplogr. foliaceus; in the latter with Diplogr. foliaceus, Climacogr.

bicornis and Dicellogr. sextans; and the Stockport specimens occur with Diplogr. euglyphus and Climacogr. parvus.

Remarks. The principal distinguishing features of this variety are the small axillary angle and the extension of the strong spines upon the beginning of the uniserial branches [*see* fig. 247]. The axillary angle is in the specimens from Glenmont and Mt Moreno still considerably smaller than in

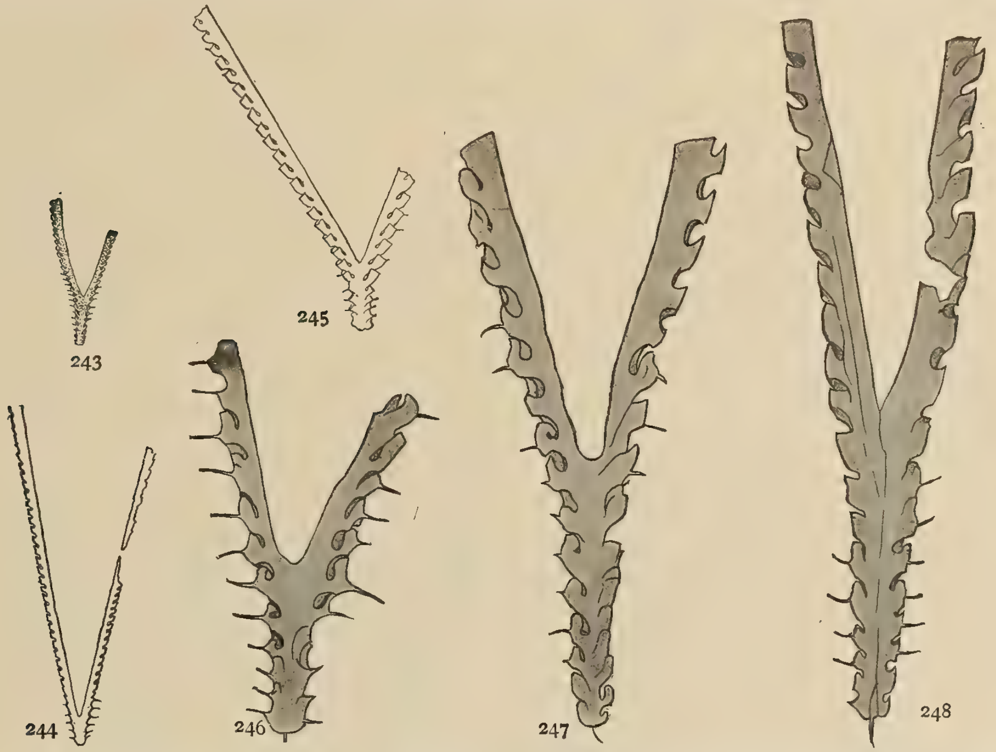

Fig. 243-48 Dicranograptus nicholsoni var. parvangulus Gurley. Fig. 243-45 Gurley's original (manuscript) figures. The original of figure 243 is from Stockport, N. Y.; those of figures 244 and 245 are from Arkansas (all three in National Museum). Figure 245 is enlarged x 2; the preceding are natural size. The originals of figures 247 to 248 are from Glenmont, N. Y. Figure 248 shows the sicula with virgella and the septum; the two other figures the character of the thecae. x 5

the Arkansas and Stockport examples and reduced to 20° [*see* pl. 21, fig. 2, text fig. 248, etc.] and less, but quite constant in all the specimens and thereby guaranteeing the constancy of the variety. Otherwise they fully agree with Gurley's type specimens. Gurley has remarked [1896, p.73] that D. whitianus Miller differs from this variety only in having all the thecae on the branches spinose, and that he would have united the two, if D. whitianus did not rest upon a single specimen from a distant locality (Nevada)

and the eastern and Arkansas specimens did not fail to show any decided approximation to the condition found in whitianus. It seems to us, however, that there exists considerable variation as to the extension of the spines on the thecae between the various rhabdosomes. In some [*see* text fig. 248] the spines do not go beyond the bifurcation, in others [text fig. 247] they extend beyond it by three or four thecae, while in others again [text fig. 246] they extend as far as the branch is preserved. It can, therefore, be well conceived that there exists a continuous series of gradations, to forms with the spines extending over the whole branch as in D. nicholsoni var. whitianus.

Dicranograptus nicholsoni var. **diapason** Gurley

Plate 21, figures 3–5

Dicranograptus nicholsoni var. diapason Gurley. Jour. Geol. 1896. 4: 73

The original description of this striking variety is:

Proximal portion with three minute spines at base, measuring from base to notch between branches five (sometimes as much as 6 mm), showing

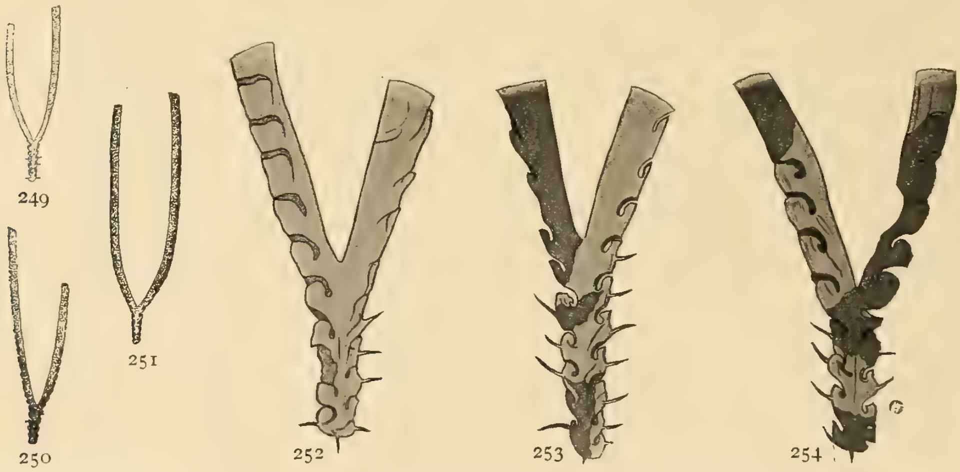

Fig. 249–54 Dicranograptus nicholsoni var. diapason Gurley. Fig. 249–51 Gurley's original (manuscript) drawings (all natural size). Fig. 252–54 Enlargements (x 5) of portions of specimens from Glenmont, N. Y. Originals of figures 249 to 251 in National Museum

below the level of the notch, at most seven (usually six, sometimes five) thecae; width of proximal portion 1.25 to 1.50 mm; branches, in the compressed condition, 1 to 1.25 mm wide; diverging at an angle of 45° (sometimes slightly less) to 50°, with a very gentle inward curve which brings

into parallelism, or even approximates them still further. Thecae forming bent tubes with the tip introverted, 24 or 25 in 25 mm; some of them (probably all on basal portion; material here uncertain) bearing an acute spine.

This variety is a well marked one. In form the most characteristic specimens approach closely D. ziczac minimus Lapw., but our form is at least twice as large as Lapworth's, and besides D. ziczac appears not to occur in our strata. From the characteristic caliper-shape as a basis, the variety shades into var. parvangulus, which has the branches straighter and continually divergent.

Horizon and locality. Lower Dicellograptus zone, Stockport, N. Y.

Remarks. Since Dr Gurley did not publish any figures of his new variety, we insert here drawings of the type specimens [text fig. 249–51], made under his supervision. The collection obtained by the State Museum in the railroad cut at Glenmont contains a finely preserved series of specimens of diapason; they are associated with Dicellogr. gurleyi, Climacogr. parvus and Glossogr. ciliatus, but not with D. nicholsoni var. parvangulus. They permit the elucidation of some additional characters of the variety.

The thecae possess strongly convex ventral walls in their free portions; their apertural parts are strongly introverted and introtorted. The septum begins after the second pair of alternating thecae. The biserial portion has the characters of D. nicholsoni and as Gurley surmised the mesial spines extend to the bifurcation [*see* fig. 253, 254]. Besides the parallelism of the uniserial branches, their most striking character is their ribbon-shaped smooth form, with straight margins, a feature well shown in Gurley's drawings. Our camera enlargements give the explanation to this character by which diapason can at once be distinguished from all other forms of D. nicholsoni. When the test is preserved, as in figure 252, one branch will give a frontal, the other a dorsal view; where one branch is preserved with the test, the other as impression, as in figures 253 and 254, both will give like views. The biserial portion at the same time gives always a profile view of the thecae. It is, therefore, evident that at the bases of the uniserial branches a torsion of the rhabdosome has taken place. This feature is probably more important and characteristic of the variety than the parallelism of the branches, for we have specimens in which the

branches diverge nearly as much as in the types of parvangulus, but they still retain their torsion [*see* pl. 21, fig. 5]. This fact would also refute the possible assumption that oblique compression of specimens of parvangulus could produce the parallelism and smooth aspect of the branches, seen in diapason.

It is probable that this torsion sets in already at the sicular end of the biserial portion, for a close scrutiny of the same will always show that if on one side the free parts of the thecae are convex and shown in their full profile view they are concave at the opposite side or seen there slightly obliquely and that this condition is reversed farther up [*see* fig. 252, 253]. We infer from these facts that in this variety a very gradual torsion of the branches takes place and that this is combined with a spiral growth of the branches as in D. furcatus; that hence the now parallel branches if found long enough would be seen to form a very long 8 and we have indeed seen a specimen in which the extremities of the branches come again in contact. D. nicholsoni var. diapason further distinguishes itself from its associates on the slabs by its strongly glossy appearance, indicating a greater thickness of the periderm than found in most other species. It is probable that this is causally connected with the torsion of the branches.

This interesting variety is known to us only from the Normanskill shales at Stockport and Glenmont, N. Y.

Dicranograptus nicholsoni Hopkinson var. **whitianus** Miller

Graptolithus (Climacograptus) ramulus White. Exped. & Sur. West 100th Merid. Prelim. Rep't. Invert. Foss. 1874. p.13

Graptolithus (Climacograptus) ramulus White. Wheeler Sur. West 100th Merid. Rep't. 1875. v. 4, pt 1, p.62; pl. 4, fig. 3a–c

Graptolithus whitianus Miller. Cat. Am. Pal. Foss. Ed. 2. 1883. p.269

Dicranograptus ramulus Herrmann. Nyt Mag. f. Naturvidensk. 1886. v. 29

Dicranograptus nicholsoni var. whitianus Gurley. Jour. Geol. 1896. 4:72, 300

The type of this form, which was obtained 5 miles north of Belmont, Nev., is in the National Museum. Dr Gurley has made the subjoined

remarks on the variety that will serve better to define the poorly preserved fossil than the original description.

This form differs from the typical D. nicholsoni of the Utica in the smaller angle (35° or 40° against 70°–80° in the Utica specimens) and in the presence of short, rigid spines on the thecae of the stem and on practically all those of the branches. In the latter feature lies its chief difference from var. parvangulus Gurley. I should add that a careful examination of the type specimen shows the proximal portion to be larger than shown in White's figure, at least six thecae being visible.

The original name being preoccupied, the variety has to pass under the name proposed by Miller in the *American Palaeontology*.

Dicranograptus ramosus Hall

Plate 21, figures 6, 7; plate 23, figure 1

Graptolithus ramosus Hall. Pal. N. Y. 1847. 1: 270; pl. 73, fig. 3

Graptolithus ramosus Salter. Geol. Soc. Quar. Jour. 1848. 5: 16; pl. 1, fig. 7

Cladograpsus ramosus Geinitz. Die Graptolithen. 1852. p.29

Cladograpsus sp. undet. Emmons. Am. Geol. 1856. pl. 1, fig. 12

Dicranograptus ramosus Hall. Can. Org. Rem. Dec. 2, 1865. p.15, fig. 20; p.112

Dicranograptus ramosus Salter? Geol. Sur. Gt. Brit. Mem. 1866. 3: 330; pl. 11A, fig. 1

Dicranograptus ramosus Salter. Siluria. Ed. 4 (1866). p.541, fig. 4

Graptolithus (Dicranograptus) ramosus Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.181, fig. 21

Dicranograptus ramosus Nicholson. Monogr. Brit. Grapt. 1872. p. 119, fig. 60

Cladograpsus ramosus M'Coy. Geol. Sur. Victoria. Dec. 2, 1875. pl. 20, fig. 2

Dicranograptus ramosus Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 4, fig 80

Dicranograptus ramosus Whitfield. U. S. Geog. Sur. West 100th Merid. Wheeler's Rep't. 1877. v. 4, Pal. p.19

Dicranograptus ramosus Walcott. Alb. Inst. Trans. v. 10. 1883 (Advance sheet. 1879. p.34)

Dicranograptus ramosus Lapworth. Roy. Soc. Can. Trans. v. 5, sec. 4. 1886. p.184

Dicranograptus ramosus Ami. Can. Geol. Sur. Rep't. Ser. 2, v. 3, pt 2. 1889. p.117K
Dicranograptus ramosus Walcott. Geol. Soc. Bul. 1890. 1:339
Dicranograptus ramosus Gurley. Jour. Geol. 1896. 4: 297
Dicranograptus ramosus Roemer & Frech. Lethaea Pal. 1897. 1: 616, fig. 180
Dicranograptus ramosus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3: 411
Dicranograptus ramosus (?) T. S. Hall. Roy. Soc. Victoria Proc. v. 9, pl. 1. 1896. p.184
Dicranograptus ramosus T. S. Hall. Geol. Mag. n. s. Dec. 4, 1899. 6: 445
Dicranograptus ramosus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.496ff
Dicranograptus ramosus T. S. Hall. Geol. Sur. Victoria Rec. v. 1, pt 1. 1902. p.33
Dicranograptus ramosus Fearnsides. Sec. C. Belfast. 1902. Separates, p.1
Dicranograptus ramosus Clark. Geol. Mag. Ser. 4. 1902. 9: 498
Dicranograptus ramosus Weller. Geol. Sur. N. J. Pal. 1903. 3: 53
Dicranograptus ramosus Elles & Wood. Monogr. Brit. Grapt. (Pal. Soc. 1904) p.175; pl. 24, fig. 6a, b
Dicranograptus ramosus Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33
Non Dicranograptus ramosus Beecher. N. Y. State Mus. Nat. Hist. 36th An. Rep't. 1883. p.78

Description. Rhabdosome consisting of a biserial portion which varies in length from 10 to 15 mm, the latter being a maximum, apparently not surpassed, and two gently concave uniserial branches forming an angle that most frequently is 25° but may rise to 30° or over; and attaining a length of 185 mm and more. The biserial portion has, in the typical specimens, an initial width of .7 mm and gradually increases to 1.8 mm; it consists of 13–18 nonspinose thecae on either side and is divided by a distinct septum from the second pair of thecae upward. The uniserial portion is frequently a little narrower (by almost .2–.4 mm) at its beginning than the remainder of the branch which is of uniform width (1–1.4 mm, with 1.2 as the prevailing average); the branches form, in the majority of the specimens, first an angle of about 40°, which at a distance of about 10 mm, is somewhat abruptly changed into the smaller angle given above. The branches are thence apparently straight, but in the most complete specimens

they are seen to begin to curve gently inward and approach again at an approximate distance of 150 mm from the point of bifurcation.

The length of the sicula has not been observed, but a short, stiff virgella is nearly always present. The first two thecae bear curved lateral spines at the points of flexure. The first two pairs of thecae grow in alternate arrangement, the following in single series separated by a septum. The thecae number 8 to 10 in 10 mm (20–25 in 1 inch), are 1.8 mm long, and overlap one half their length; their ventral walls are gently convex, the apertural parts strongly introverted and introtorted, contained in and apparently nearly entirely filling round excavations that occupy one third the width of the branch and equal in length more than one half the free part of the thecae.

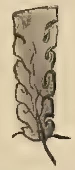

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Fig. 255, 256 Dicranograptus ramosus Hall. Fig. 255 Sicular portion of a rhabdosome showing the sicula and virgella (x 5 from Stockport, N. Y. Original in National Museum). Fig. 256 Copy of Hall's figure in Decade II [pl. A, fig. 20]. *See also* text figure 41

Position and localities. D. ramosus is common in the Normanskill shale at Kenwood and Stockport; it also occurs in the same horizon at the Moordener kill, at Mt Moreno and at several localities about Troy (as at Mt Olympus). In several outcrops, as those of Glenmont and Mt Moreno, it is very rare and replaced by varieties which occur there profusely. It does not seem here to go in its typical form above the Normanskill shale. Gurley [1896, p. 71] claims to have observed a much more slender variety in the Upper Dicellograptus zone at Magog, Quebec, while Whitfield [1877, *loc. cit.*] and Gurley have cited it from the Utica shale of the Mohawk valley. The Mohawk valley specimens were stated by Whitfield to have come from Oxtungo creek. Slabs from that locality covered with specimens of a Dicranograptus are preserved in the State Museum but the latter prove to belong to a spinose mutation [*see* below]. Frech [1877, p.616] has cited it also from Saratoga lake in New York. The only form known to the writer from that locality is D. nicholsoni. D. ramosus has also been found in the Normanskill shale of New Jersey by Weller and has been early recognized by Lapworth

and Ami in the equivalent beds of the province of Quebec in Canada; and Gurley has also recorded it from the Dicellograptus zone in Arkansas.

In Great Britain D. ramosus is, according to the monographers, by no means so common as in the Normanskill shale of this State; it is but rarely found in the corresponding Glenkiln shales and more frequently in the following Lower Hartfell shales. It is there known from Scotland, Wales and Ireland; McCoy and T. S. Hall record the species also from the province of Victoria, Australia.

Remarks. The fragmentary rhabdosomes of graptolites, scattered pell mell over the slabs, are liable to form very deceptive, though but accidental groups. One of these has been mistaken by Hall for a more complete rhabdosome and been figured [*loc. cit.* pl. 73, fig. 3f] and described as "a specimen branched below, and bifurcating above." The figure shows — and the original leaves no doubt about it — that here two rhabdosomes have come into such position that the sicular end of one has fallen upon the point of bifurcation of the other, thereby giving the impression of a continuous biserial portion with four uniserial branches. Unfortunately it is just this figure that has entered into some of our textbooks of geology, thereby perpetuating a misconception of one of our most striking Normanskill graptolites.

The sicular extremity of the rhabdosomes is not well shown in any of the specimens; the most distinct of them is reproduced in figure 255. It exhibits the virgella, the lateral spines and their position on the thecae; and the growth directions of the primary thecae. As far as the evidence of this and another specimen goes, the origin of the first thecae in this species is like that described for the whole genus by Elles and Wood. The alternate arrangement of the thecae does not seem to continue beyond the first four thecae, for the sutural line of a dividing septum has been observed in several specimens to begin directly above them.

a Dicranograptus ramosus var. arkansasensis Gurley

Dicranograptus arkansasensis Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:416; pl. 9, fig. 1, 2

Dicranograptus nicholsoni arkansasensis Gurley. Jour. Geol. 1896. 4:72

Cf. Dicranograptus ramosus Elles & Wood. Monogr. Brit. Grapt. pt 4. (Pal. Soc. 1904) pl. 24, fig. 6b

Gurley's brief description of this species, given in his preliminary publication, is:

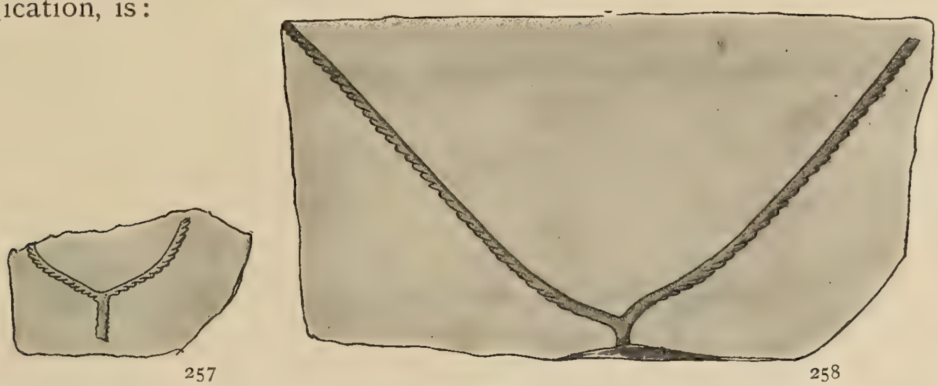

Fig. 257, 258 Dicranograptus ramosus var. arkansasensis Gurley. Copies of Gurley's figures in Geological Survey of Arkansas, Annual Report 1892. Drawing too wide by one half

Proximal portion 9 mm long; branches diverging at an angle of 90° to 130°, curving upward at a short distance from their origin so as to include a smaller angle; thecae 20 in the space of 25 mm; nonspinose.

Horizon and locality. Lower Dicellograptus zone, Arkansas.

We have nothing to add to this description from an inspection of the type material, the specimens being so poorly preserved that barely more than the general outline of the rhabdosomes can be made out. As we have remarked before, this form is quite probably identical with the variety of D. ramosus recognized by Elles and Wood in Great Britain, but not named by them. In general outline it closely agrees with our D. spinifer var. geniculatus, except that the biserial portion is shorter, indicating thereby and by the nonspinosity of the thecae its closer relationship to D. ramosus than to D. spinifer. The flexure in the Arkansas specimens is almost as abrupt as in the variety from New York, but not brought out sufficiently in the original drawings.

Dicranograptus spinifer Lapworth

Plate 22; plate 23, figures 2, 3

Dicranograptus ramosus Hopkinson. Geol. Mag. 1870. 7: 358, pl. 16, fig. 5

Dicranograptus ramosus Lapworth. Belfast Nat. Field Club. Rep't & Proc. Apx. 1877. v. 1, pt 4, p.140; pl. 7, fig. 1

Dicranograptus spinifer Lapworth. Geol. Soc. Quar. Jour. 1882. 38: 610

Dicranograptus ramosus var. spinifer (Lapworth ms) Elles & Wood. Monogr. Brit. Grapt. pt 4 (Pal. Soc. 1904) p.176; pl. 24, fig. 8a–c

Elles and Wood describe two varieties of D. ramosus, viz, var. spinifer and var. longicaulis. The former of these is in certain outcrops of the Normanskill shales, the common representative of D. ramosus, while the latter has not yet been observed here. It is stated of the var. spinifer, that Lapworth already recognized it in 1877 and that it is characterized "by (*a*) the fusiform shape of the biserial portion which is also considerably longer than that of the typical form, and (*b*) by its strongly spinose thecae." These characters are also well shown in our specimens [*see* plate 22]. The length of the biserial section varies considerably, viz, from 8 mm to 27 mm, the width is .5 mm at the sicular extremity and may rise within 10 mm to 2 mm, to decrease again slightly towards the bifurcation. The final angle formed by the uniserial branches is undoubtedly a little larger than in the typical ramosus and averages 40°, but may rise to 45°. On the other hand the uniserial branches of most specimens are markedly narrower than those of the typical form, and falling below 1 mm, while at the same time the thecae are more widely arranged (but 8–9 in 10 mm, *see* figure 263) and provided with rather long excavations. The mesial spines do not seem to extend in any of the specimens to more than a dozen thecae on either side, independently of the number of thecae in the biserial section (which may rise to 25 on either side in our material); while of the British specimens it is stated that "All the thecae of the biserial portion (with the possible exception of some of the distal ones) are provided with long and stout mesial spines." The New York form is, hence, again varying from the British variety in some of its features.


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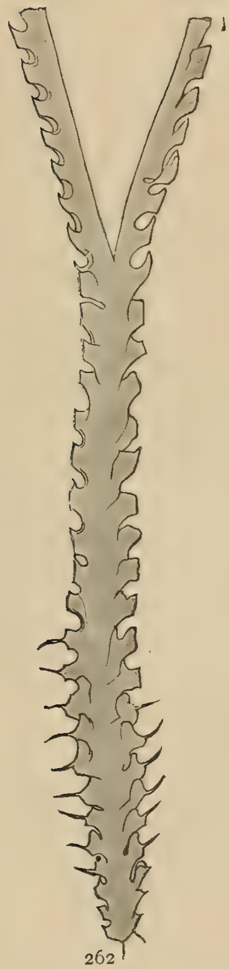
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Fig. 259–64 *Dicranograptus spinifer* Lapworth. Fig. 259 Sicular end of a specimen showing the sicula. Original from Stockport, N. Y. and in National Museum. Fig. 260 Portion of uniserial branch. Fig. 261 Portion of biserial branch partially infiltrated with pyrite and preserving the original form of the thecae. Figures 262 and 263 show the character and length of the biserial portion. The originals of figures 260 and 262 from Mt Moreno; those of figures 261 and 263 from Glenmont. Fig. 264 A somewhat poorly preserved specimen from the Utica shale at Dolgeville, possibly a *ramosus*. All are enlarged x 5, except figure 261 which is enlarged x 7.

We have preferred to consider this form as a full species for several reasons, the principal one of which is that there exists again a distinct and characteristic variety of it in D. spinifer var. geniculatus, which fact indicates the thoroughness of the final separation of D. spinifer and D. ramosus.

Position and localities. In the Normanskill shale at Mt Moreno but one or two fragments of ramosus have been observed, while this species is there the dominant form of one of the layers [*see* plate 22]. It is there associated with Climacogr. parvus and Lasiogr. mucronatus. It is also the prevailing form at Glenmont, from where I have before me a specimen, one of whose fragmentary uniserial branches reaches the remarkable length of 164 mm. It is associated with Climacogr. parvus, Lasiogr. mucronatus, Dicellogr. gurleyi, etc. There are also a few specimens from the Stockport collection referable to this species.

Finally the specimens from the Utica shale at Oxtungo creek, a southern affluent of the Mohawk river, which have been referred by Whitfield and Gurley to D. ramosus, represent quite evidently a late mutation of this type; for they possess the fusiform biserial portion, the somewhat greater angle of bifurcation of the branches [*see* pl. 23, fig. 2] and also the mesial spines can be seen in spite of the poor preservation of the old museum specimens to which the above mentioned authors had reference. The biserial part of the rhabdosome is not longer than in ramosus. These specimens are associated with Leptobolus insignis and Climacogr. typicalis.

A slab of the museum collection, ticketed as Utica shale and of unknown locality, bears besides the Utica mutation of Climacogr. typicalis and Corynoides curtus var. comma large and typical specimens of D. spinifer, identical in their characters with the Mt Moreno individuals.

In Great Britain this form occurs in S. Scotland in the Glenkiln and Lower Hartfell shales (Balclatchie beds).

a Dicranograptus spinifer var. geniculatus nov.

Plate 23, figures 4–6

The most striking of the forms of Dicranograptus is a variety of D. spinifer which is characterized by (1) the stoutness of the branches, (2) a flexure of the uniserial branches, (3) the extension of the mesial spines over the entire or nearly entire biserial portion of the rhabdosome.

This variety is by its strongly fusiform biserial portion and the extension of the mesial spines close to the bifurcation nearer related to the British representatives of D. spinifer than to any other form. It also has in common with the latter the greater width of the biserial portion (2 mm) and of the uniserial branches, which in some specimens have a uniform width of 1.6 mm. Also its spines are longer than those of our other representatives of Dicranograptus and the ventral walls of the thecae markedly more convex. Its test is stronger than that of the other species and varieties and it seems to have been an altogether more robust form.

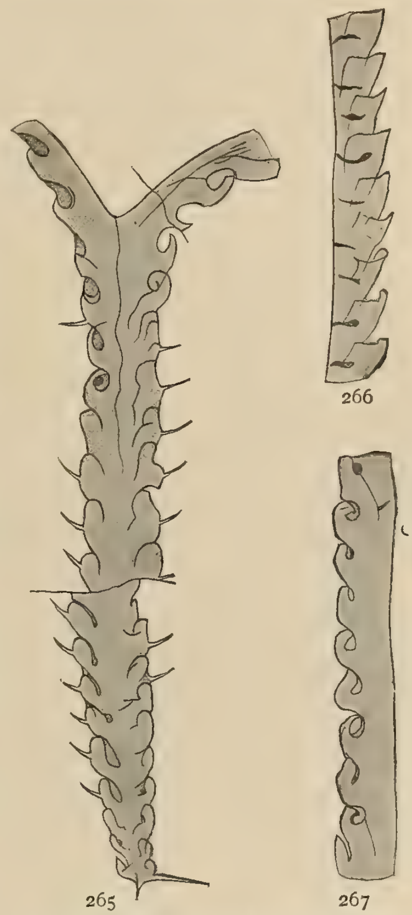

Fig. 265–67 Dicranograptus spinifer var. geniculatus nov. Figure 265 shows characters of biserial portion. Figure 266, part of the uniserial portion of the same specimen; figure 267, that of another. Glenmont, N. Y. ×5

A similar flexure as that observed in this variety had been noticed by Elles and Wood in specimens of D. ramosus [*op. cit.* pl. 2b, fig. 6b], and a general tendency to such a development has been observed in our material of D. ramosus [*see* pl. 21, fig. 7]. The above cited authors remark "should the discovery of more examples prove that this latter form was a permanent one, it would be worthy of a varietal name." It is very probable that D. arkansasensis Gurley

from the Dicellograptus zone of Arkansas [*see* p. 329] is identical with the variety of D. ramosus here referred to. The British geniculate form being nonspinose, it represents a parallel development in D. ramosus to that here observed in D. spinifer.

In the extreme forms [*see* pl. 23, fig. 4] the branches become horizontal after the bifurcation, and resume afterwards by an almost rectangular flexure a direction corresponding to that of the branches in the main species.

Position and localities. This variety has been mainly observed in the Normanskill shale at Glenmont, N. Y., associated with Climacogr. parvus, Lasiogr. mucronatus and Dicellogr. gurleyi and in one specimen also at Mt Moreno in association with Diplogr. foliaceus, Climacogr. bicornis and Dicellogr. sextans.

Dicranograptus furcatus (Hall)

Plate 23, figure 7

Graptolithus furcatus Hall. Pal. N. Y. 1847. 1: 273; pl. 74, fig. 4a–f

Dicranograptus furcatus Hall. Can. Org. Rem. Dec. 2. 1865. p.15 ff, et al.

Dicranograptus furcatus Lapworth. Ann. & Mag. Nat. Hist. 1880. 5: 283

Dicranograptus furcatus Walcott. Alb. Inst. Trans. v. 10. 1883 (Advance sheet. 1879. p.34)

Dichograptus furcatus Whitfield. Am. Jour. Sci. Ser. 3. 1883. 26: 380

Dicranograptus furcatus Walcott. Geol. Soc. Bull. 1890. 1: 339

Dicranograptus furcatus Gurley. Jour. Geol. 1896. 4: 297

Dicranograptus nicholsoni Frech. Lethaea Pal. 1897. 1: 617, fig. 181

Description. Rhabdosome of medium size, consisting of a short biserial portion (2.3–2.5 mm long, 1 mm wide, and composed of eight thecae) and two uniserial branches, which grow upward in oppositely directed spirals, forming in the compressed condition a series of successive elliptic loops and diverging at the point of bifurcation at an angle of 40° to 90° (in compressed state). The width of the branches is uniform in every specimen, with variations from .9 to 1.1 in different individuals. The sicular extremity is squarish, provided with a small virgella and inconspicuous lateral spines. The sicula is short and blunt, about .8 mm long; the first two thecae grow horizontally outward and then turn abruptly upward. The thecae are short

(2 mm long) and broad, number 12 to 14 in 10 mm and overlap one third their length; their ventral wall is highly convex in the distal part and the apertural part strongly introverted and introtorted, lying within a deep, but short round excavation, that occupies nearly one half the width of the branch and one third the length of the theca. All the thecae possess long, straight and rigid mesial spines.

Formation and localities. Hall's types came from the Normanskill shale at the Normanskill below Albany. Gurley reports it from the outcrop of the same horizon at Stockport and the New York State Museum contains slabs from Glenmont which are densely covered with this form. At Stockport it is associated with Diplogr. angustifolius, Climacogr. parvus, Glossogr. ciliatus, Dicranogr. ramosus, Nemagr. gracilis and exilis; in Glenmont with Didymogr. sagitticaulis, Didymogr. subtenuis, Diplogr. foliaceus and Cryptogr. tricornis. It is also very common in a suite of specimens collected by Walcott 2½ miles north of Middle Granville, north of the Mettanee river. There it is associated with Diplogr. foliaceus and Nemagr. gracilis. Elles and Wood have described a smaller variety of this species, D. furcatus var. minimus, which they state to be fairly abundant in some of the Scottish localities of the Glenkiln shales and to occur also in Ireland and Wales.

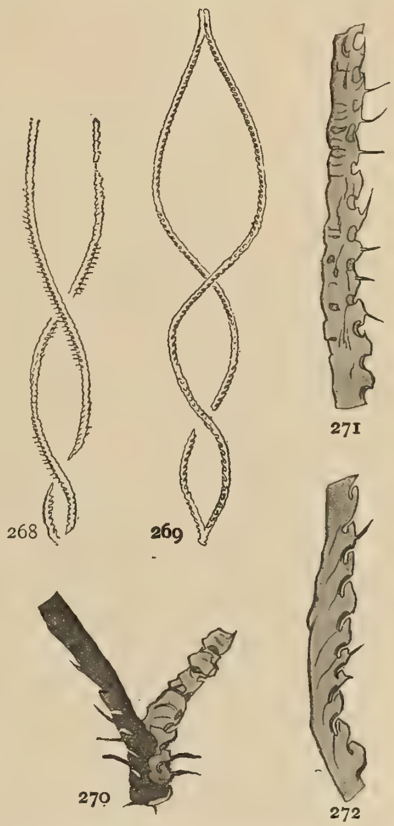

Fig. 268-72 **Dicranograptus furcatus** (Hall). Fig. 268, 269 Gurley's manuscript drawings of Stockport specimens. Nat. size. Originals in National Museum. Fig. 270-72 Camera enlargements (x 5) of portions of specimens from Glenmont, N. Y., showing the form of the thecae

Remarks. Hall's original drawings of D. furcatus which show the characteristic aspect of the form, represent with one exception small

fragmentary specimens, retaining about one half of the first loop. Curiously enough this is by far the most common mode of occurrence of this species and whole slabs may bear nothing but these fragments. Elles and Wood's statement that "the stipes of var. minimus have never been observed to meet, whereas in D. furcatus they typically cross," indicates that also in the British variety the fragmentary occurrence is the more common one. Specimens of D. furcatus which cross several times have been seen by me only in the Stockport collection [*see* fig. 268, 269]. Gurley (1896) has investigated these and concluded from the alternate position of the thecae, in the compressed state, on the inside and outside of the loops, from the crossing of the branches at different levels and their crossing alternately over and under, that they "originally grew spirally upward, each describing an oppositely directed curve," adding that judging from the figures, probably also Lapworth's species Dicellogr. caduceus and Dicranogr. ziczac grew in continuous spirals. We have at another place [p. 112] brought forward evidence to prove that the spiral growth of the branches was a general feature in the Dicranograptidae.

The periderm of the rhabdosome must have been very thick in this species, if we judge rightly from the strongly glossy appearance and the smaller amount of compression, as compared with the associate species, features which are especially apparent in the Glenmont suite of specimens. That this thickness of the test was in some way connected causally with the relative compactness of the spirals in D. furcatus, is hardly to be doubted.

In D. furcatus the convexity of the distal part of the theca and the introversion and introtorsion of the apertural part appear to have reached their extreme development. On account of these short, high bosses of the thecae and the thickness of the periderm the branches have in their ventral and dorsal aspects a curious beaded or shortly segmented appearance which is quite characteristic of the species [*see* right branch on fig. 270].

Dicranograptus furcatus var. **exilis** nov.

Plate 23, figure 8

In the Normanskill shale at Kenwood a variety is found whose branches are barely half as wide as those of the typical form (their width =.5-.6 mm). It thereby presents a much differing aspect. Since the thecae are not more closely arranged (they number 12 in 10 mm), they must be relatively longer and narrower. Also the mesial spines are considerably finer and hardly noticeable. No other differences have been observed and the variety seems to be very rare.

Dicranograptus contortus sp. nov.

Plate 23, figure 9

Description. Rhabdosome very small, in the contorted condition but 7 mm long, but the length of a branch was traced to 21 mm; consisting of

273 274 275 276 277 278

Fig. 273-74 Dicranograptus furcatus var. exilis nov. Enlargements (x 5) of biserial and uniserial portions of specimen from Kenwood, N. Y.

Fig. 275-78 Dicranograptus contortus sp. nov. Fig. 275, 276 Enlargements (x 5) of typical rhabdosomes. Fig. 277 Biserial portion of a specimen showing the form of the thecae. Fig. 278 The most frequent aspect of the branches. x 5

a short biserial portion, which is 3 mm long and .8 mm wide, and contains five thecae on either side and of relatively thick, uniserial, uniformly wide (.7 mm) branches which in the compressed specimens are intricately contorted. The sicular extremity is rounded, furnished with long virgella and conspicuous lateral spines. The sicula has not been observed. The thecae are short and wide, very closely arranged, numbering 18 to 20 in the space of 10 mm; overlapping apparently one third of their length; the ventral

wall of the distal parts very convex, in the thecae of the biserial portion (and perhaps also in the others) furnished with short mesial spines. The apertural part strongly introverted and introtorted; contained in a deeply curved excavation which occupies about two fifths the width of the branch.

Position and localities. A small slab of Normanskill shale from Kenwood, N. Y. was found to be covered with specimens of D. contortus, in association with Cryptogr. tricornis. A few specimens were also found in the same formation at Mt Olympus in Troy, associated with Climacogr. parvus.[1]

Remarks. This most curious form has in the compressed state all the appearance of much segmented worms which have coiled before death and only the spinose biserial portions which here and there connect the pairs of enrolled branches indicate the true nature of the fossil, naturally surmised from the association and strong periderm. The branches were evidently round in section, furnished with strong periderm and originally like the other Dicranograpti coiled into oppositely directed spirals which seem to have been short and compact. The contortions are clearly of post-mortem origin, and resulting from the wiry character of the branches.

There has been no species of Dicranograptus described with which this one could be confused; it differs from all by its small size, contorted branches and close arrangement of thecae, but it is clearly a diminutive member of the group hitherto represented by D. furcatus Hall and D. ziczac Lapw., characterized by extreme spirality of the branches, highly convex ventral walls of the short thecae, strongly introverted and introtorted apertural parts and more or less spinosity of the thecae. In all these characters the paracmic condition of the genus becomes apparent.

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[1] The writer has also observed a characteristic specimen on a slab from the western graptolite shale, but having failed to properly mark it at the time of the discovery, has not been able to find it again.

Suborder B GRAPTOLOIDEA AXONOPHORA Frech

Family DIPLOGRAPTIDAE Lapworth

DIPLOGRAPTUS McCoy

The history, astogeny and morphology of this important genus have already been briefly noted in Memoir 7 [p.528, 718]. The structure and development of the rhabdosome have been there set forth according to Wiman's observations and those of the synrhabdosome according to the writer's. In regard to the latter observations, it is, however, to be stated that the growth-stages of the synrhabdosome, which, at the time of their publication, were referred to D. foliaceus, have, together with the form currently here considered as D. pristis Hall (=D. foliaceus Murchison) been since recognized by the writer to represent a variety of D. quadrimucronatus Hall, which in its turn is in this paper placed under Glossograptus. Since the true D. foliaceus forms synrhabdosomes exactly corresponding to those of Glossogr. quadrimucronatus and other biserial Axonophora (Lasiograptus is here also shown to grow in synrhabdosomes), there can be but little doubt, that the astogenetic stages of Diplograptus correspond to those of Glossogr. quadrimucronatus published by the writer.

We figure here a few of a series of fine synrhabdosomes of D. foliaceus which the Normanskill shale at Glenmont near Albany has afforded and which leave no doubt that the complete colony of that stately Diplograptus formed a dense bush of rhabdosomes radiating from a central organ, which however, on account of the density of this branching, could not be discerned. We also, in this connection, refer the reader to the figures of synrhabdosomes of Glossogr. quadrimucronatus and G ? eucharis given under these species. They are camera-enlargements of specimens that were reproduced rather crudely in free-hand drawings by the writer in a former paper on this subject, and show some of the central organs.

The relation of the first theca to the sicula and its original distal growth direction and later reverse, as well as the budding of the second

theca from the first and its crossing to the other side of the rhabdosome, are all observable in favorably preserved shale material of D. foliaceus [fig. 286, 287] and other species. The sicula is seen to be furnished in most species with a long needlelike virgella and an opposite short mucro. The "lateral spines" which are also frequently developed into powerful spurs [*see* fig. 286] are apertural spines of the two primary thecae [*see* p.72 of introduction]. In typical Diplograpti they are restricted to these two thecae.

We have here excluded the spinose forms from Diplograptus for the reason set forth in the introduction [p.85] that with the development of spinosity changes in the structure of the perisarc take place which are of generic value. All spinose forms are here united under Glossograptus and, for practical reasons, even such forms are brought under that caption in which the perisarcal structures are not quite apparent, as G. (?) eucharis. Thus restricted the genus Diplograptus comprises, in the faunas here described, only D. foliaceus with its many varieties and mutations (var. acutus, alabamensis, incisus, trifidus and mut. vespertinus), D. crassitestus, D. amplexicaulis (and var. pertenuis), D. angustifolius, D. euglyphus and D. peosta.

In no genus of graptolites does one encounter greater difficulties in distinguishing the species than in this. Three reasons can be readily cited for this troublesome fact, namely the great differences in the aspects of the flattened shale material and of the limestone and shale material preserved in relief, the protean variety of aspects of the same form according to the different directions of compression and the sides of the rhabdosome facing the viewer and finally the multitude of varieties and mutations. These combined produce such a confusing number of similar, but still distinct, forms that one is tempted to distinguish but very few, widely varying species, as has been done hitherto; but the fact that in certain layers of the beds, with definite associations of graptolites, or in one locality but one variety of the species is found, makes the differentiation of all these forms imperative. The origin of the differing aspects of the rhabdosomes of D. foliaceus has been set forth with great clearness by Professor Lap-

worth in his manuscript report to Dr Gurley and the two most important American varieties of the species have been elaborately described. Both of these valuable contributions to our knowledge of this species have been incorporated in this paper [p. 344ff].[1]

Lapworth has successively distinguished four subgenera of Diplograptus, viz, Orthograptus and Glyptograptus [1874] and Idiograptus and Gymnograptus [1880]. Two of these have strongly spinose forms for types (Orthograptus quadrimucronatus and Idiograptus aculeatus) which are here placed under Glossograptus and should, in the writer's opinion, be regarded as subdivisions of that genus. Gymnograptus is a *nomen nudum* [1880, p.22] and according to a ms note of Dr Gurley, based upon information from Professor Lapworth, allied or identical with Idiograptus. This would leave Glyptograptus alone available for a subdivision of Diplograptus as here conceived. Awaiting a final and more complete grouping of the species of Diplograptus under Lapworth's supervision in the *Monograph of British Graptolites*, we have here refrained from referring our types to any of these subgenera.

Diplograptus appears in the last of the Deepkill zones, obviously attains its climacteric development — evinced in variety of forms, size and multitude of individuals — in the Trenton shales and rapidly disappears on this continent towards the end of the Champlainic, after shrinking in both variety of form and size.

Diplograptus foliaceus (Murchison)

Plate 24, figures 1–8; plate 25, figures 1, 2

? Fucoides dentatus (Brongn.) Conrad. N. Y. State Sur. 2d An. Rep't. 1838. p.114

? Fucoides dentatus Vanuxem. *Ibid.* p.283

Graptolithus foliaceus Murchison. Sil. Syst. 1839. p.694; pl. 26, fig. 3

? Graptolites dentatus Vanuxem. Geol. N. Y. 3d Dist. 1842. p.56 with fig.

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[1] Professor Lapworth desired to revise his views on D. foliaceus and its varieties expressed in this manuscript report and bring them into accord with those of the *Monograph of British Graptolites* but was unfortunately prevented from doing so.

? Graptolites dentatus Emmons. Geol. N. Y. 2d Dist. 1843. p.279 with fig.
? Graptolites dentatus Hall. Geol. N. Y. 4th Dist. 1843. p.29
? Graptolites dentatus Mather. Geol. N. Y. 1st Dist. 1843. p.393 with fig.
Graptolithus foliaceus Portlock. Geol. Rep't. 1843. p.320; pl. 19, fig. 9
Graptolithes pristis (parte) Hall. Pal. N. Y. 1847. 1:265; pl. 72, fig. 1a–s
Diplograptus secalinus (Eaton) Hall. Pal. N. Y. 1847. 1:267; pl. 72, fig. 2a–c
Fucoides simplex Emmons. Tac. Syst. 1844. p.27; pl. 5, fig. 1
Fucoides simplex Emmons. Agric. N. Y. 1847. v. 1, pl. 17, fig. 1
Graptolithus folium et G. pristis Salter. Geol. Soc. Lond. Quar. Jour. 1849. 5:15, 16; pl. 1, fig. 5, 6 ?
Diprion foliaceus Harkness. Geol. Soc. Lond. Quar. Jour. 1850. v. 7, pl. 1, fig. 13b
Diplograptus foliaceus Geinitz. Die Grapt. 1852. pl. 1, fig. 29, 30
Diplograptus pristis Marcou. Geol. Map U. S. 1853. p.24; pl. 1, fig. 10
Diplograptus rugosus Emmons. Am. Geol. 1856. p.105; pl. 1, fig. 26
Diplograptus dissimilaris Emmons. *Ibid.* p. 105; pl. 1, fig. 5
Graptolithus pristis Hall. Pal. N. Y. 1859. 3:516, fig. 2
Graptolithus pristis Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p.60, fig. 2
Graptolithus pristis Hall. Can. Org. Rem. Dec. 2. 1865. p. 36, fig. 30
Diplograptus barbatulus Salter. Mem. Geol. Sur. Gt. Brit. 1866. v. 3, pl. 11A, fig. 1e, d
Diplograptus pristis Carruthers. Geol. Mag. 1868. 5:130; pl. 5, fig. 13a–d
Graptolithus pristis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p. 204. 205, fig. 2
Diplograptus pristis Hopkinson. Queckett Micr. Club Jour. 1869. v. 1, pl. 8, fig. 11a
Diplograptus pristis Nicholson. Monogr. Brit. Grapt. 1872. fig. 22, 26, 50
? Diplograptus pristis Hopkinson & Lapworth. Geol. Soc. Lond. Quar. Jour. 1875. 31:656–57; pl. 35, fig. 7a–g
Graptolithus (Diplograptus) pristis (Hall) ? White. Rep't Wheeler Survey. 1875. 4:65; pl. 4, fig. 2
? Graptolithus (Diplograptus) hypniformis White. Rep't Wheeler Survey. 1875. 4:63; pl. 4, fig. 4a, b
Diplograptus foliaceus Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 2, fig. 29

Diplograptus foliaceus Lapworth. Belfast Nat. Field Club Rep't & Proc. v. 1, pt 4, Apx. 1877. p.133; pl. 6, fig. 18

Diplograptus foliaceus Linnarsson. Sver. Geol. Und. Ser. C, no. 31. 1879. p.16 ff

Diplograptus rugosus (Emmons) ? Lapworth. Ann. Mag. Nat. Hist. 1880. 6:168

Diplograptus foliaceus Tullberg. Sver. Geol. Und. Ser. C, no. 41. 1880. p.20

Diplograptus pristis Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet, 1879. p.34)

Diplograptus foliaceus Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p.20

Diplograptus pristis Whitfield. Am. Jour. Sci. Ser. 3. 1883. 26:380

? Diplograptus pristis Tullberg. Zeittschr. d. deutsch. geol. Ges. 1883. 35:241

Diplograptus foliaceus Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:177 ff

Diplograptus foliaceus Ami. Can. Geol. Sur. Rep't. Ser. 2, v. 3, pt 2, 1887–88. 1889. p.117K

Diplograptus foliaceus et pristis Geinitz. Mitth. k. Min. geol. praeh. Mus. Dresden. 1890. 9:37, pl. A

Diplograptus pristis Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Diplograptus foliaceus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:404

Diplograptus foliaceus Barrois. Ann. Soc. Géol. du Nord. 1892. 20:145

Diplograptus foliaceus Gurley. Jour. Geol. 1896. 4:298

Diplograptus foliaceus T. S. Hall. Roy. Soc. Proc. 1896. 9:185

Diplograptus foliaceus T. S. Hall. Roy. Soc. Proc. 1897. 10:14

Diplograptus pristis (in part) Ruedemann. N. Y. State Geol. Rep't. 1894. 1897. p.219, pl. 4

Diplograptus foliaceus T. S. Hall. Geol. Mag. n. s. Dec. 4. 1899. 6:445

Diplograptus foliaceus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.497 ff

Diplograptus foliaceus Clark. Geol. Mag. Ser. 4. 1902. 9:498

Diplograptus foliaceus T. S. Hall. Geol. Sur. Victoria Rec. v. 1, pt 1. 1902. p.34 f

Diplograptus foliaceus T. S. Hall. Geol. Sur. N. S. Wales Rec. 1902. v. 7, pt 2, p.4; pl. 12, fig. 7

Diplograptus foliaceus Weller. Geol. Ser. N. J. Pal. 1902. 3:53

Diplograptus foliaceus T. S. Hall. Geol. Sur. Victoria Rec. 1904. v. 1, pt 3, p.219

Diplograptus foliaceus Ami. Geol. Sur. Can. Sum. Rep't. 1905. p.12

Diplograptus foliaceus T. S. Hall. Geol. Sur. Victoria Rec. 1906. v. 1, pt 4, p.275

There is no form which is so common in the New York Trenton shales and at the same time so perplexing by the variability of its aspects as D. foliaceus. I therefore gladly avail myself of the opportunity of giving here instead of my own observations, Lapworth's welcome description of the species and of its two Normanskill varieties, which is contained in his manuscript report sent in 1890 to Dr Gurley. These descriptions were based on a collection of Normanskill graptolites from Stockport, Columbia co., N. Y.

On D. foliaceus itself, Professor Lapworth has made the following remarks:[1]

Of all the Diplograptidae there are none which are so difficult of separation and determination as those which paleontologists are at present in the habit of referring to D. foliaceus Murchison and its varieties; or to the associate and doubtfully separable ally D. rugosus Emmons.

They range in geological time from the horizon of D. pristiniformis Hall, to that of D. quadrimucronatus, and curiously enough exhibit all the characters intermediate between these two well marked species. They all possess the same type of rhabdosome (polypary), nemacaulus (virgula) and theca; but differ extraordinarily among themselves as regards (1) size, (2) number of thecae, (3) degree of lateral and proximal ornamentation.

The rhabdosome (polypary) in all of these forms is of the general shape of a prism of quadrangular section, with rounded ends. (The section is about twice as broad from back to front as from side to side.) The proximal part of the rhabdosome (polypary) converges to an abrupt extremity, furnished with a radicle and two lateral spines; but in the distal parts the margins of the rhabdosome (polypary) are parallel.

The *nemacaulus* (virgula) is remarkably stout, is marked often by a central groove and is prolonged in antisicular direction (distally) to a length somewhat less than that of the rhabdosome itself. A straight seam or

[1] For the sake of uniformity of terminology the writer has inserted the terms used in this memoir, wherever different ones were used, and added the latter in parentheses.

suture marks one of the faces of the rhabdosome throughout the greater part of its length, except in the neighborhood of the sicular (proximal) extremity, where for some distance the test is continuous and unbroken.

Each *theca* is of the form of a subprismatic tube about three or four times as long as wide, and with a longer (back to front) diameter about twice that of the shorter (lateral) width. The lower part of the theca is crushed inwards forming a well marked "excavation." The upper part is free and somewhat sacculate. It is limited above by a horizontal apertural margin. This margin is frequently edged by a thickened rim or "welt" and is furnished at each of its corners with a stumpy horizontal spine.

The surface of the rhabdosome is smooth throughout.

This especial type of rhabdosome naturally admits of becoming compressed in a variety of different aspects which at first sight appear to be characteristic of very distinct species.

(α) In the ordinary or mid-*profile* view (the sutural line being exactly central in position on the specimen) the rhabdosome becomes compressed symmetrically, the margins of the rhabdosome are constituted by the mid section of the theca. This is Murchison's original view [*see* Silurian System]. The spines are invisible but the compressed "*welt*" projects in an upward and inclined direction as a well marked "mucro."

The apertural margin is concave and the lateral margin convex above and bent into the excavation below.

(β) In the quarterface view, a very frequent one, we see the rhabdosome so compressed that the left spinose corner of the theca on the one side, and the right spinose corner of the theca on the opposite margin lie on the margin of the fossil, and the flattened thecal edge looks almost straight. This is one of the most frequent and easily understood appearances. We have a fossil which while it reminds us of Diplo. quadrimucronatus is nevertheless easily separable.

(γ) We may have an angle of compression intermediate between α and β. Some of the spines may show, but being cut at angle, only very inconspicuously. The "welt" however becomes in this case very conspicuous and the apertural margin of each theca becomes broadly concave.

The scalariform views are simpler and easy of interpretation.

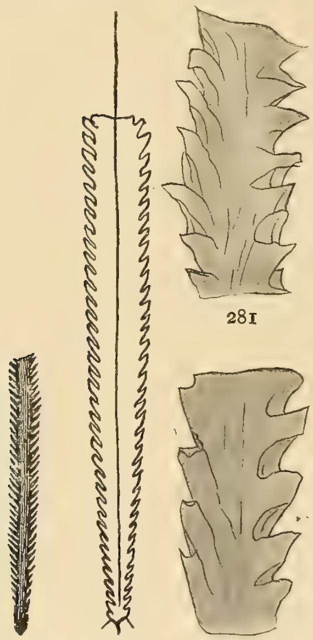
It is not at all unlikely that the characters we regard here as specific, are actually subgeneric, but as yet our evidences are imperfect, and will probably remain so until we can study many specimens of the types and varieties in relief.

In the meantime it is safest to regard the several recognizable subforms as varieties of D. foliaceus.

One of the varieties occurring in the Stockport shales is identical with my var. acutus from S. Scotland, Shropshire, Conway ? and Lower

Canada. The other is also found in Lower Canada viz, D. foliaceus var. incisus.

The relationship of all these forms to Diplo. pristis Hisinger is very close. Indeed we may yet have to return to Hall's first view and make D. foliaceus a variety of D. pristis. The Swedish forms of D. pristis are preserved in demirelief and in different rock to our British graptolite bearing sediments but in the present state of our knowledge I should probably place their D. pristis if I found it here as a variety of D. foliaceus.



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279 280 282

Fig. 279–82 Diplograptus. Fig. 279 Copy of the figure of "Graptolithus dentatus" of the First Survey. Fig. 280 Hall's figure of Diplograptus pristis in Pal. N. Y. vol. 3. Fig. 281 Diplograptus foliaceus from Murchison's locality (x 6½). Fig. 282 Diplograptus pristis from Hisinger's locality (x 7). The last two figures original (manuscript) drawings by Lapworth

Professor Lapworth has added to his manuscript report rubbings of camera drawings of typical specimens of the two varieties of D. foliaceus, which he found in the Stockport collection. By means of these it has been an easy task for the writer to recognize the two types in the collections from the outcrops of Normanskill shale in the State and to establish the fact of their presence in all the more important ones. The actual constancy of the differences is guaranteed by the fact that the slabs will usually contain the rhabdosomes of but one of them, often in great numbers and that the two are not found on the same synrhabdosome or so associated that it would become probable that they grew as parts of one synrhabdosome.

We insert here Lapworth's descriptions of the two varieties with a few alterations made to attain uniformity, adding such observations as are permitted by the larger collections which we have at our disposal. Besides these two, several more varieties or rather mutations had to be recognized, whose descriptions follow.

a **Diplograptus foliaceus** var. **incisus** Lapworth

Plate 24, figures 1-8

Graptolithus pristis Hall (non Hisinger). Pal. N. Y. 1847. v. 1, pl. 72, fig. 1r

Description. Length of rhabdosome 25 mm to 45 mm; maximum width 3 mm, with parallel distal (antisicular) margins, but converging throughout its lower half to a pointed sicular extremity, the first two thecae of which are provided with short lateral spines. Nemacaulus distinct, broad, double, in antisicular direction prolonged to a distance equal to one fourth of the length of the rhabdosome. Thecae 8 to 9 in the space of 10 mm (20–22 to 1 inch), inclined at an angle of 45° to 50° with the nemacaulus; ventral margin broadly concave, and pressed inwards deeply in the lower half to form a deep excavation; apertural margin horizontal or slightly inclined; occupying one third of the width of the rhabdosome and originating a broad pointed denticle. Surface smooth and unornamented.

The characteristic features of this species are constituted by the broadly convex edges of the thecae and the large and deeply concave apertural margins, forming between them a broad triangular denticle. The edge of each theca does not show the deep interspace so well seen in D. angustifolius, the interspace itself being often reduced to a mere oblique triangular slit with convex margins; the apertural edge alone reaching the outer boundary of the rhabdosome; the thecae appear to become broadly sacculate in the upper third of their length, and the margin of the aperture crosses a larger proportion of the periderm than in any other species known to me. Judging from the various aspects presented by the thecae, it would appear that the central part of each apertural margin is the most prolonged, but except in the initial theca it is only usually produced into a point which has a slightly ascending direction. The lateral depression of the sides of the apertural margins, gives a curious appearance to certain compressed specimens; a row of cavities or hollows running down the rhabdosome midway between the axis and the general margin in the profile view. This is most conspicuous in specimens preserved in slight relief.

The affinities of this species are certainly with D. pristiniformis Hall, from which it differs in general form, in width and the number of thecae to the inch; and also in the amount of inclination. Its relationship with D. foliaceus var. acutus and other varieties is much closer.

Loc. ½ mile below Little Méchin Point (415), Lower Canada and Stockport, Columbia co., N. Y.

Author's remarks. This is the most common of the New York Normanskill forms. The collection of the State Museum obtained at Glenmont near Albany contains synrhabdosomes [*see* pl. 24, fig. 5] and rhabdosomes

which in dimensions [*see* pl. 24, fig. 4] considerably surpass the figures given by Lapworth. The synrhabdosomes exhibit upward of 50 rhabdosomes — but probably consisted of many more since only the short-stemmed rhabdosomes are retained and broken-off long-stemmed rhabdosomes are extremely common on the slabs — and attain a diameter of 15 cm, but probably reached still much larger diameters, for the longest rhabdosomes, which are also those with the longest free stems, are obviously most liable to get lost. Separate rhabdosomes measuring over 10 cm (without the nemacaulus) and nemacauli reaching 7.5 cm have been observed [*see* pl. 24, fig. 1, 4], indicating a possible combined length of rhabdosome and nemacaulus of 17.5 cm and a diameter of the synrhabdosome of 35 cm or 14 inches. With this form the genus Diplograptus attained here clearly its maximal development both in size and frequency.


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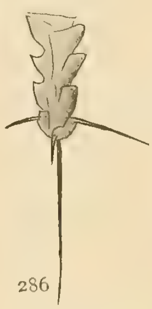
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Fig. 283–87 Diplograptus foliaceus var. incisus Lapworth Fig. 283, 284 Lapworth's original figures of Stockport specimens (x 6½). Fig. 285 Portions of well preserved mature specimen from Glenmont (x 7). Fig. 286, 287 Sicular ends of rhabdosomes, showing the sicula and spines (x 5)

The nemacaulus is, in contrast to the size of the rhabdosomes and to the nemacauli of other varieties, remarkably thin and not surpassing .1 mm in width. Its extreme thinness in this, the largest variety, is the more remarkable since the stoutness of the nemacaulus of D. foliaceus has been pointed out as a noteworthy feature by Professor Lapworth, who added that its broad straplike structure is suggestive of a welt upon one surface of the rhabdosome. A maximum width of 1.5 mm has been recorded for the

nemacaulus in compressed specimens of D. foliaceus. The thinness of the nemacaulus in our material is especially noticeable in the numerous specimens from Glenmont, in which it is coupled with extreme length [*see* pl. 24, fig. 1], making the feature the more striking. Since Lapworth in his description of D. foliaceus var. incisus expressly mentions the broad character of the nemacaulus, it is possible that these Glenmont forms again represent a different variation, which is also suggested by the fact that many of the rhabdosomes possess as many as 10 thecae in 10 mm. On the other hand the rhabdosome and thecae would not seem to differ sufficiently in shape to warrant a differentiation.

The sicular end though mostly protected only by the two short lateral spines, will sometimes possess a longer (4 mm), straight virgella [*see* text fig. 286] and a minute second sicular spine.

In the largest rhabdosomes the maximum width increases to 4 mm and the number of thecae in 10 mm sinks to 8 (20 to the inch). In others again, which still present the characters of this variety, the number of thecae rises to almost 10 in 10 mm (24 to the inch). The figures for the thecae should therefore be probably extended from 8 to 10 (20–24 to the inch instead of 20–22).

b **Diplograptus foliaceus** Murchison var. **acutus** Lapworth

Plate 25, figures 1, 2

Graptolithus pristis Hall (? Hisinger). Pal. N. Y. 1847. v. 1, pl. 72, fig. 10, 1p

Description. Rhabdosome from 25 to 40 mm in length, with a maximum diameter of 3 mm; margins parallel for the final three fourths of their length; converging slowly towards the sicular end which is furnished with a central and two short lateral spines; about 1.25 to 2.50 mm in length. Thecae 11 to 12 in 10 mm (28–30 to 1 inch), inclined at an angle of about 50° (40° and over), overlapping for about one third of their length; the free ventral margin crushed inwards below to form a well marked excavation, and convex above, the edge becoming finally perpendicular. Apertural margins of each theca horizontal, and usually slightly concave, the denticle which is often bordered by a slight ridge being slightly introverted, and in flattened specimens, prolonged into a short and slightly inclined spine.

The most peculiar characteristics of this form are (1) the number and form of the thecae, their frequently convex apertural edge, with its projecting, oblique denticle or short horizontal spine.

Fig. 288–93 Diplograptus foliaceus var. acutus Lapworth. Fig. 288 Lapworth's original (manuscript) drawing of Stockport specimen (x 6½). Fig. 289–93 Different aspects of specimens mostly due to different direction of compression. Fig. 292 A partially infiltrated specimen. All enlarged x 5

It is closely allied on the one hand to D. pristis His. and D. foliaceus var. incisus and on the other to the remaining varieties of D. foliaceus, differing from all of them, however, in size and the number of thecae in a given space.

Loc. Stockport, Columbia co., N. Y.; ½ mile above Little Méchin river, lower Canada; Glenkiln beds of S. Scotland (common), Upper Llandeilo beds, Middleton, Shropshire (frequent).

We have found this variety to be most common in the shale from Mt Moreno, where D. foliaceus var. incisus is rare, while the present variety completely covers some layers. Some of the specimens are infiltrated with pyrite and preserved in full relief [*see* text fig. 292]. No synrhabdosomes have been observed; the rhabdosomes are markedly smaller and narrower than in the preceding variety and the thecae so much more closely arranged that the difference is easily noticeable to the naked eye. The virgella is frequently much prolonged. The nemacaulus is broad and straplike and in one case [*see* pl. 25, fig. 2] undoubtedly inflated and showing its central virgula.

Certain slabs of the collection from the Normanskill shale at Glenmont near Albany contain nothing but a smaller variety of this form [*see* pl. 25, fig. 1]; the rhabdosomes while possessing all the true characters of this variety, are uniformly smaller, hardly more than 20 mm long and 2 mm wide. This type approaches in length closely to D. angustifolius, a form of similar thecal shape but always remains notably broader.

c **Diplograptus foliaceus** var. **trifidus** Gurley

Cf. Diplograptus foliaceus var. calcaratus Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 1, fig. 30

Diplograptus trifidus Gurley. Geol. Sur. Ark. Rep't. 1890. 3:417; pl. 9, fig. 3, 4

Diplograptus trifidus Gurley. Jour. Geol. 1896. 4:298, 307

Dr Gurley has described in the Annual Report of the Geological Survey of Arkansas a large Diplograptus which occurs in that state in chocolate-brown limestone in association with the Dicellograptus fauna and which is a striking form in several regards. It is of large size, attaining 60 mm in length and 6 mm in width and possesses a very broad nemacaulus (2 mm) suggesting the inflated one of D. vesiculosus. It is most conspicuous, however, by the three powerful spines of its sicular end, a long daggerlike virgella and two strong, curved lateral spurs. Its thecae number 8 to 10 in the space of 10 mm and are those of a foliaceus.

295

294

Fig. 294, 295 Diplograptus foliaceus var. trifidus Gurley. Copies of Gurley's original figures

Gurley was at the time of drawing up his description not aware of the fact that Lapworth had already proposed the variety calcaratus of D. foliaceus for a form with just such strong terminal spurs. Later [1896, p.307] he has stated that though "the identity of the two forms can hardly be asserted at present as Lapworth's calcaratus rests solely upon the figure of a basal fragment," he would not have described D. trifidus

had he had access to Lapworth's figure. While these varieties of D. foliaceus upon close comparison may be hardly or not at all distinguishable, the fact remains that they appear in widely separated regions or basins and seem to be absent in intermediate areas as in the east of North America. They might therefore represent independently developed varieties whose deceptive uniting would lead to wrong inferences.

d **Diplograptus foliaceus** var. **alabamensis** nov.

Plate 25, figure 3

Description. Rhabdosome long and slender, attaining a length of 35+ mm and a width of 1.5–2 mm; beginning with a narrow sicular end, .8 mm wide and increasing slowly in width, attaining its full width in about 10 mm. Sicular end marked by small virgella and lateral spines. Free nemacaulus not observed. Thecae numbering 9 to 11 in 10 mm; with convex ventral and horizontal or slightly inclined apertural margins, overlapping one half of length, inclined at angle of 45°.

Position and locality. In the calcareous Trenton shales of Pratt's Ferry, Bibb co., Ala.

Remarks. This, the only representative of Diplograptus in the suite of graptolites from the Trenton shales of Alabama, differs from the material obtained in our State, by its remarkable slenderness. In this and the form of the thecae in the usual state of preservation, it recalls D. angustifolius, but differs from that species in the form of the rhabdosome (more gradual widening) and looser arrangement of thecae. Still, it could perhaps with equal propriety be referred to that species as a variety and seems to stand in its character between a narrow D. foliaceus var. incisus and D. angustifolius. From D. euglyphus it is easily distinguished by the much shorter interthecal excavations.

e **Diplograptus foliaceus** mut. **vespertinus** nov.

Plate 25, figures 4, 5

Diplograptus pristis (parte) Hall. Pal. N. Y. 1847. v. 1, pl. 72, fig. 1, 1a, 1b, 1k, 1l

Description. Synrhabdosome not observed. Rhabdosomes as a rule short (15 mm, greatest length observed 42 mm), widening gradually from

an initial width of 1 mm to a maximum width of 2.5 which is attained in a distance of 15 mm from the sicular extremity and then maintained. Sicula not observed. Sicular extremity furnished with a short blunt virgella (about .4 mm long) and two equally short straight lateral spines. Thecae numbering 11 to 13 in 10 mm (30–32 in 1 inch), inclined at an angle of 30°–40°, overlapping a little more than one third, the outer margin distinctly convex with the proximal part frequently slightly concave. The aperture horizontal, concave, the interthecal excavation about one fourth the width. Nemacaulus very thin and inconspicuous within the rhabdosome and not seen protruding beyond the antisicular end.

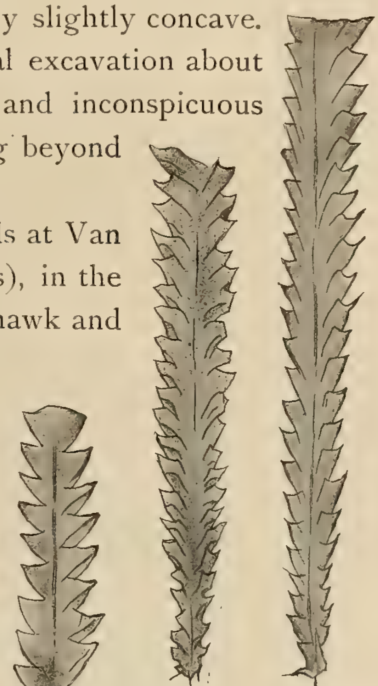

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Fig. 296–98 Diplograptus foliaceus mut. vespertinus nov. Fig. 296 Early type (Van Schaick isl.). Fig. 297 Late type (Ward's lane). (x 5) Fig. 298 Enlargement (x 5) of one of the rhabdosomes in the group, reproduced by Hall in plate 72, figure 1a

Position and locality. In the transition beds at Van Schaick island (with Cryptogr. tricornis), in the Utica and Lorraine shales of the Hudson, Mohawk and Black river regions.

Remarks. This mutation of D. foliaceus is in the form of the rhabdosome and the form and close arrangement of the thecae most nearly related to D. foliaceus var. acutus and quite evidently a direct descendant of the same. It is the last representative of the group of D. foliaceus in our rocks and persists into the Lorraine beds. In the beds at Van Schaick island, which may be properly referable to the Upper Dicellograptus zone, it is the most common graptolite and there it attains its maximum size [296]. In smaller individuals it fills layers of the Utica shale, as in the neighborhood of Amsterdam in the Mohawk valley. It further occurs in the uppermost Utica beds around Albany, as at Ward's lane, Black rock, etc. and in the Lorraine beds, whence Hall's type of D. pristis [pl. 72, fig. 1a, 1b=298 which typically represents this mutation] came. The gradual widening of the rhabdosome, the small size of the denticles and

the correspondingly great relative width of the middle face of the rhabdosome, as well as the close arrangement of the thecae are the most characteristic features of this mutation. From the associated forms in the Utica shale it is readily distinguished by these characters and from D. peosta, with which it is associated in the Lorraine beds, by the greater width attained and its more gradual widening.

Diplograptus crassitestus sp. nov.

Plate 25, figure 6

Description. Synrhabdosome not observed. Rhabdosomes with thick test and of large proportions, length of largest (incomplete) specimen 41 mm, its width 2.2 mm at one extremity and 1.8 mm at the other, and 3 mm in another specimen; very gradually widening, quadrilateral in section, with the lateral faces twice as wide as the frontal ones. The lateral faces smooth, both slightly concave and with a faint median sutural line. Sicula not observed. Sicular end narrow (.6 mm wide), furnished with a small virgella (2 mm long). Thecae numbering 7 to 10 in 10 mm (18–25 in 1 inch), three times as long as wide, subrectangular in section, overlapping one third their length; inclined at an angle of 30° to 40°, the outer margin straight, often convex, impressed or even excavated (especially in the older thecae) in the proximal part; aperture perpendicular to axis, apertural margin straight or slightly concave, occupying one fourth the width of the rhabdosome. Nemacaulus thick, mostly short.

299

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Fig. 299, 300 Diplograptus crassitestus sp. nov. Fig. 299 Young rhabdosome. Fig. 300 Portion of mature rhabdosome. (x 5)

Formation and localities. Sylvan shale, Arbuckle mountains, Indian Territory. Collected by Dr E. O. Ulrich, who informs me that the Sylvan shale is younger than the Richmond beds.

Remarks. This species is, of the eastern American varieties of D. foliaceus, most nearly related to D. foliaceus var. **incisus**

and it can be easily conceived that the limestone specimens which are plastically preserved would, if compressed in shale, present the general aspect of that Normanskill form. Still the thecae in their mature parts are distinctly farther apart than those of D. foliaceus var. incisus and the whole form is correspondingly coarser in its habit than even this largest Diplograptus of the New York beds. In the latter feature it reminds strongly of D. foliaceus var. trifidus, an earlier form of the same region.

Synonymy of Diplograptus foliaceus

Among the synonyms of D. foliaceus there have been cited here a number of Emmons's species. In doing this we have followed Gurley's list of American graptolites [1896, p.97] since it appears from his manuscript notes, printed below, that he had made special efforts to clear up the synonymy of these extremely bad species. These species are:

D. dissimilaris *Emmons*, 1856
D. laciniatus *Emmons*, 1856
D. obliquis *Emmons*, 1856
D. rugosus *Emmons*, 1856
D. simplex *Emmons*, 1844

Says Gurley:

Relative to the synonymy of this species the name first applied to it in America was Fucoides secalinus, Eaton. We have the authority of Professor Hall[1] for the statement that this was never published by Professor Eaton himself. Professor Hall says:

"The Graptolithus, from the Hoosic slate quarries was named by Professor Eaton, Fucoides secalinus, and the specimens were thus labeled in the cabinet of the Rensselaer school at Troy, as known to the writer from 1832 to 1836 but we have been unable to find any published descriptions."

This species was first published in America by Dr Emmons[2] (under the name Fucoides simplex) in 1844. It is the only one to which the name simplex Emmons is properly applicable. To define it more clearly it is the one which includes as synonyms the pristis (Hisinger) Hall, secalinus (Eaton) Hall, amplexicaulis Hall and several other names. It is to be most carefully distinguished from two other

[1] Hall, James. 1865, Can. Org. Rem. Dec. 2, p.64 and *id.* N. Y. State Mus. Nat. Hist. 20th An. Rep't. 1868. p.233.

[2] Emmons, Ebenezer. Taconic System, p.27, t. 5, f. 1.

species which have since been published under the same name but which have no specific (and a very questionable generic) affinity with it.

The first of these is Dr Emmons's Diplograptus secalinus (Eaton) of 1856.[1] In the synonymy there given Fucoides simplex Emmons [1844, above] is regarded as a synonym for and is suppressed in favor of Professor Eaton's species. As pointed out above this view of the affinities of Fucoides simplex, Emmons (of 1844) and Graptolithus secalinus (Eaton) Hall (of 1847) is correct, but with this correct synonymy Dr Emmons published figures of an entirely different species.

Thirdly we have Mr Walcott's "Diplograptus ? simplex, Emmons"[2] and (which is the same species) a different generic reference of "Phyllograptus ? simplex Emmons."[3]

Relative to this species Mr Walcott says:[4]

"Dr Emmons originally applied the name Fucoides simplex to a species previously named by Professor Eaton as Fucoides secalinus. Subsequently he referred the species named by him to Eaton's F. secalinus calling it Diplograptus secalinus, gave a description as above, and at the same time figured another species which we have found in the fine silicious shales of Parker's ledge. For this I have decided to use Emmons's name simplex, the name D. secalinus being restricted to the species from the Hudson River Group as described by Professor Hall."

Mr Walcott thus perceived the distinctness of Emmons's "Diplograptus secalinus Eaton" of 1856 from the same author's simplex of 1844 and its synonym Hall's secalinus (Eaton) of 1847. He believed that he had rediscovered Emmons's secalinus of 1856 in the Parker's ledge quarries and acting upon this belief proposed to apply Emmons's name simplex to this species. An examination of his figure (and of the type specimen) shows however that this species is entirely distinct from all the others.

In order to render this exceedingly complex synonymy clear the following table is given:

simplex Emmons, no. 1

simplex, Emmons, 1844, Tac. Syst. p.27, t. 5, f. 1; Graptolithus (Fucoides) secalinus (Eaton) Hall, 1847, Pal. N. Y. I, p.267, t. 72, f. 2a–c; includes as synonyms D. pristis (Hisinger) Hall, D. amplexicaulis Hall etc., etc. Horizon, Trenton to Lorraine.

Proper name D. simplex, Emmons

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[1] Emmons, Ebenezer. Am. Geol. pt 2, p.104, t. 1, f. 11.

[2] Walcott, C. D. 1886. U. S. Geol. Sur. Bul. 30. p.92–93, t. 11, f. 4, 4a.

[3] Walcott, C. D. 1889. Am. Jour. Sci. 37: 388.

[4] *Loc. cit.* p.92.

simplex Emmons, no. 2

The "Diplograpsus secalinus, Graptolithus secalinus (Hall), Fucoides secalinus (Eaton) F. simplex (Emmons)" of Emmons, 1856, Am. Geol. pt 2, p.104, t. 1, f. 11. It is far better that this "simplex, Emmons" should disappear from nomenclature forever and I therefore propose for this species the name Diplograptus ? prionoides (sp. n.). I do so with the less reluctance as the figure shows it to be strikingly distinct from any other species with which I am acquainted. I have not seen the specimen.

Its horizon is doubtful. Dr Emmons says: "It is confined to the Hoosic roofing slate." This is true of the preceding species ("simplex Emmons no. 1") but that is the only fossil that has ever been found in those shales, and it is almost certain that "simplex, Emmons, no. 2," was not found there.

Proper name D. ? prionoides Gurley (sp. n.)[1]

simplex Emmons, no. 3

"Diplograptus ? simplex, Emm.," and "Phyllograptus ? simplex Emmons" Walcott (references above). For this species Mr Walcott now proposes the name Echinograptus (=Phyllograptus Hall) ? cambrensis (sp. n.). Horizon, Lower Cambrian (Georgia shales of Vermont).

Proper name E. cambrensis Walcott (sp. n.)

Concerning the specific relations of this form, Mr C. D. Walcott (U. S. Geol. Sur. Bul. 30, 1886, p.92–93) says:

"*Original description.* Straight; serrations pointed, cells rather distant oblique to axis; the serration equal in length to one sixth or one seventh of the width of the stem. The upper or young part of the stem is 3/8 inch wide and the number of serrations is 24 to an inch. It narrows towards the base, where the serrations are rather obtuse and more distant than those above, and is 10 inches long as exposed upon the slate. It is confined to the Hoosic roofing slate.

Dr Emmons originally applied the name Fucoides simplex [Tac. Syst. 1844, pl. 5, fig. 1; N. Y. Agric. Rep't, pt 5, 1846, pl. 17, fig. 1] to a species previously named by Prof. Amos Eaton [*see* N. Y. State Mus. Nat. Hist. 20th Rep't, 1868, p.268] as Fucoides secalinus. Subsequently he referred the species named by him to Eaton's secalinus, calling it Diplograptus secalinus, gave a description as above, and at the

[1] Since this "species" would possess neither an original description, nor a recognizable figure, nor even a type or type locality, it is hopelessly invalid and better not recognized from the start; while *D. simplex* Emmons no. 2. is to be dropped from consideration for the same reasons. *See also* Dr Gurley's remarks below [p. 358]

same time figured another species which we have found in the fine argillaceous shales of Parker's ledge. For this I have decided to use Emmons's name simplex, the name D. secalinus being restricted to the species from the Hudson River group, as described by Professor Hall [Pal. N. Y. v. 1, 1847, p.267].

The specimens from Vermont are completely flattened in the shale, and are small as compared with the stipes described by Dr Emmons, as the largest one is scarcely 2 inches in length and the small ones have much the same appearance as the compressed frond of a Phyllograptus, but the similarity between the figure given in his *American Geolcgy* and the central portion of the longer fronds from Vermont is so marked that I think they are identical. Dr Emmons states that the known locality was in the Hoosic slate, but I suspect, from his having worked to the north in Washington county, N. Y. he may have procured the specimen figured from some other place, referring the slate to the same geologic age as that at Hoosic; this is the more probable, as a similar confusion of localities is to be detected in other parts of his work. The details of the description are drawn apparently from the small specimen figured, rather than from the distorted specimens usually observed in the Hoosic slate. In several of the Vermont specimens there is a strong, round, central axis, as shown in figure 4, of plate xi, that appears as though a hollow axis had been filled with sediment in a more or less complete manner, thus preserving the form of the axis, while in other specimens it was compressed and all traces of it lost."

In the course of my work I have subjected all of Emmons's species to as thoroughly critical a study as possible. I endeavored (with Mr Walcott's aid) to ascertain whether Emmons's types are in existence. Through the courtesy of Professor Clarke, of Williams College, Massachusetts (which institution purchased Emmons's collection) I was permitted to examine all the graptolites in the college museum. None of these, however, proved to be Emmons's types. I was thus thrown back upon a careful comparison of the data furnished by Emmons's text and figures. In the case of the present species, it is I think possible to say with a considerable degree of certainty (1) that Emmons's figure is what he stated it to be, viz: Diplograptus secalinus Eaton (Fucoides secalinus Eaton, F. simplex, etc.) or a (probably preservation facies) variety of D. foliaceus Murch., and (2) that Mr Walcott's "Diplograptus ? simplex Emmons" [U. S. Geol. Sur. Bul. 30, 1886, p.92–93, pl. 11, fig. 4, 4a] bears no relation to Emmons's species. For Emmons's text [Am. Geol. 1856, pt 2, p.204] states that: "The upper or young part of the stem is 3/8 inch wide, and the number of serrations is 24 to an inch. It narrows towards the base. . . . It is confined to the Hoosic roofing slate."

Turning now to his figure [*loc. cit.* pl. 1, fig. 11] we find the *width* 17/32 inch and the number of thecae 16 to the inch. In other words, his figure

is simply one and one half times the natural size. Admitting this (which seems to me almost certain) I see no reason to question Emmons's identification, or any necessity for doubting his statement that "It is confined to the Hoosic roofing slate." I have seen numerous examples of D. foliaceus Murchison (*in forma* secalinus Eaton) from those beds and many of them agree very well with Emmons's description and figure. In passing I may note that the remainder of Emmons's text tends to confuse these views.

That the species (cited above) found by Mr Walcott in the lower Cambrian (Georgia) shale of Parker's ledge could not be identical with the species indicated either by Emmons's text or the one which (on the supposition that his figure is natural size) he figured, is shown (apart from other considerations) by the *extreme disproportion between the thecae in the same space.* Thus Mr Walcott's figure (stated to be "natural size") shows 36 to 40, Emmons's text states 24 and Emmons's figure shows 15 or 16 to the inch, the last as I have shown above corresponding to the enlarged scale.

a D. rugosus Emmons

As already suggested by Professor Lapworth [Ann. & Mag. Nat. Hist. 1880, v. 5, p.168–69] this form should I think be approximated to D. foliaceus Murchison. Pending an examination of material from Emmons's locality (Parrottsville, Tenn.) it will perhaps be better to retain the name varietally, although I strongly suspect it is rather a preservation facies than a *bona fide* variety.

Fig. 301 Diplograptus rugosus Emmons. Copy of original figure

b D. dissimilaris Emmons

This form is only an obliquely compressed facies of D. foliaceus Murchison. Among the specimens from Magog (Upper Dicellograptus zone) I saw one which completely paralleled Emmons's figure; indeed the latter might have been practically reproduced from it.

c D. obliquis Emmons. 1856

Am. Geol. v. 1, pt 2, p.106, fig. 22

"Straight, serrations turned obliquely outward, exposing the mouth of the cell.

The substance of the graptolite is olive-green; thin and membranous. There are 24 cells in an inch. The sides are similar; axis, if any, concealed. Found in Augusta county, Virginia."

This species is another preservation facies of D. foliaceus Murchi-

son. At any rate I have seen many specimens of the latter species which correspond exactly to Emmons's figure. The number of thecae (24) enforces this view.

Like most of Emmons's species this is founded upon fragmentary, not to say wretched material. The characters upon which he relied for specific distinctions possess almost absolutely no value and in no other American author's work are seen so many bad species based upon variable preservation facies.

d **Diplograpsus** ? sp. indet.

Emmons, 1856. Am. Geol. pt 2, p.236, pl. 1, fig. 3

"It is thin olive-green and foliaceous, but its characters too obscure to be determined with certainty."

The only subsequent reference to this form appears to be that by Mr Walcott, who regards this form as identical with his Climacograptus emmonsi. But comparison of his [U. S. Geol. Sur. Bul. 30, 1886, p.94] description with Emmons's figure shows that this is impossible. For apart from the great difference in the aspect of the two forms arising from a difference in the ratio of the squarish so called "denticles" to the interspaces and also the great difference between the ratio of the length of the "denticles" to their breadth, the number of "denticles" (that is the number of thecae) is entirely different. Mr Walcott's description of C. ? emmonsi calls for 10 indentations in a distance of 11 mm, where the polypary is 4 mm broad. Emmons's fragment is 4.5 mm broad, *but it only has 5 or 6* thecae to 11 mm, or taking the number in the usual comparison, we have for C. ? emmonsi about 23 to 25 mm (1 inch) as against 12 in the same space for Emmons's form. Indeed the latter in a complete specimen would appear not to have so many, as the last theca and its interspace indicates a number of only 8 in the space of 25 mm (1 inch).

Can we place Emmons's species? Not very satisfactorily in the absence of all data, especially locality and horizon. There is one American species the general aspect of which it closely resembles, viz: C. parvus Hall. On the supposition that Emmons's figure is about three times natural size, the form and dimensions of the polypary and the number of the thecae and also (but perhaps to a slightly less extent) the proportions of the length to the breadth of "denticles" and the ratio of the latter to the interspaces, correspond fairly well with C. parvus. While all this is so and while this is, as far as I can see, the only approximate reference of this fragment, I can not feel any overweening confidence in the identity as it is hard to see how Emmons could have found a fragment of C. parvus without finding numerous perfect specimens associated with it. Still he apparently was accustomed to rest satisfied with poor material, probably such as came first to hand upon superficial search.

e **Diplograptus** (*sp. undet.*) Emmons. 1856

Am. Geol. v. 1, pt 2, p.236–37, t. 1, fig. 3

"It is thin, olive-green and foliaceous, but its characters too obscure to be determined with certainty."

In this opinion of Emmons I concur.

From our own observations on the various preservation facies of the Diplograpti, we fully concur in Gurley's views on the invalidity of Emmons's species. In regard to the supposed characters of D. secalinus it seems that preceding authors have not taken sufficient notice of the extreme distortion that all of the specimens in the Hoosic Falls slates have undergone by the position of the slate in the zone of extensive folding in the Taconic mountains. We present on plate 25 the tracings of three specimens from one slab, showing clearly the effect of longitudinal stretching on some specimens [fig. 7] and that of endwise compression on specimens lying at right angles to the former [fig. 9]. In the stretched specimen the number of thecae has sunk to 5 in 10 mm (13 in 1 inch) and in the other risen to 11 (28 in 1 inch); the average (8, resp. 20) which is shown by the third specimen, inclined about 45° to the direction of the principal strain in the slate, is that of a D. foliaceus of the group of D. foliaceus var. incisus, with which the Hoosic specimens also agree in their average dimensions — the great diversities in the length and width of the rhabdosomes also being caused by orogenic forces — and, as far as it can be made out, in the form of the thecae. The extreme and misleading width of some rhabdosomes is due to the combined action of endwise compression and strong flattening.

Diplograptus (Glyptograptus) amplexicaulis (Hall)

Plate 25, figures 10–13

Graptolithus amplexicaule Hall. Pal. N. Y. 1847. 1:79, pl. 26, fig. 11a, b

Diplograpsus amplexicaule Emmons. Amer. Geol. 1856. p.336, pl. 7, fig. 11a, b

Graptolithus amplexicaule Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. pl. 3, fig. 6, 7

Diplograptus amplexicaulis Lapworth. Roy. Soc. Can. Proc. & Trans. 1886. 4:184

Diplograptus amplexicaulis White. N. Y. Acad. Sci. Trans. 1895. 15:93

Diplograptus foliaceus mut. amplexicaule Gurley. Jour. Geol. 1896. 4:298

Diplograptus (Glyptograptus) amplexicaulis Frech. Lethaea Pal. 1897. 1:632

Diplograptus amplexicaulis Ruedemann. N. Y. State. Mus. Bul. 39. 1901. p.497 ff

Description. Synrhabdosome not observed. Rhabdosomes of moderate dimensions (maximum length 45 mm, maximum width 4 mm), rapidly attaining the full width (in distance of 10 mm), which is then maintained; convex on obverse side, and concave on reverse side, both marked by the interlocking thecal walls but without septal sutures. Sicular extremity furnished with thin short virgella and two minute, straight lateral spines. Sicula small (1.2 mm) and slender. Thecae tubular, with broadly subrectangular section, not growing exactly in the axial plane of the rhabdosome, but curving towards the reverse side (thereby causing the concavity of the rhabdosome) with slightly curving thecal walls (outer margins slightly convex), numbering 13 to 14 in 10 mm (32–34 to the inch), inclined 30°–40°, overlapping one third, apparently without apertural mucros. Nemacaulus not observed.

Position and localities. In middle and upper Trenton limestone at Trenton falls, at Middleville, Herkimer co., N. Y. Very common in black shale at Bakers falls (Sandy Hill), Washington co., N. Y., where it fills a great thickness of rocks, in association with Corynoides gracilis, etc.

Remarks. Hall's original description is: "Stipes slender, linear, elongated, surrounded by small sheathing folioles or scales giving it a serrated appearance; folioles small, acute." The original figures were taken, as the type shows, from a specimen retaining mostly the impression only and therefore narrower than the actual specimens.

In the 20th Museum Report [1867] the same author has furnished two very accurate enlargements of fragments of rhabdosomes, showing distinctly

the concavo-convex section and the imbricated aspect of the lateral sides. Gurley has then in his published lists of the North American graptolites cited this form as D. foliaceus mut. amplexicaule, and in the synonymy of his manuscript it is brought as a synonym under D. foliaceus var. incisus. The same author states in a manuscript note:

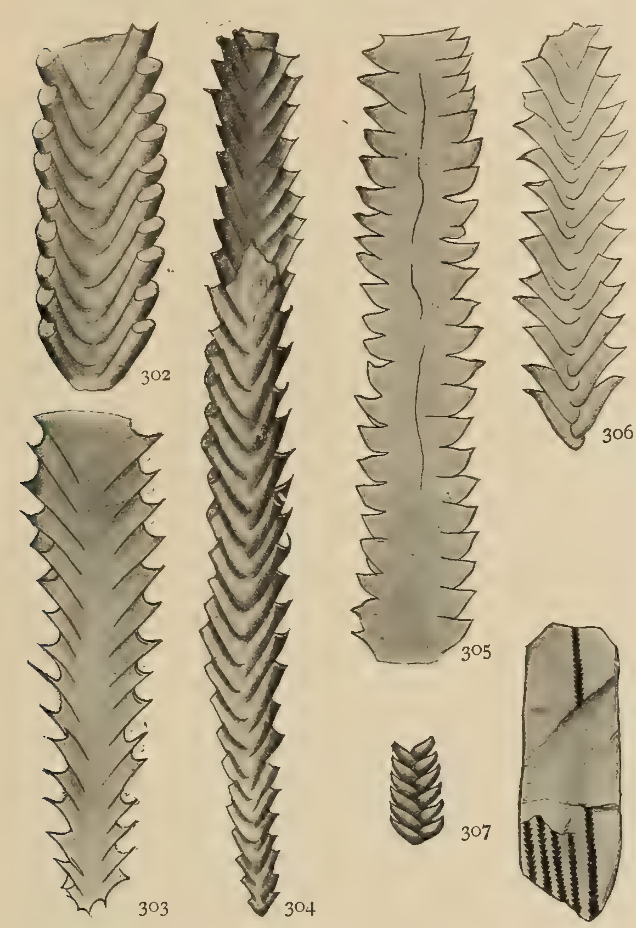


Fig. 302–7 Diplograptus amplexicaulis (Hall). Fig. 302 Portion of reverse view of rhabdosome of typical specimen, preserved in relief. Fig. 303 Impression of obverse side in limestone. Fig. 304 Narrow specimen showing flat reverse side preserved in relief, and impression of highly convex obverse side. The originals of figures 302 to 304 are from the Trenton limestone at Middleville, N.Y. Fig. 305 Much flattened specimen showing "rugosus" state of preservation. From the shale at Sandy Hill, N. Y. Fig. 396 A better preserved specimen from the same locality. All x 5. Fig. 307 Copy of Hall's original figures

In some specimens from the Utica shale of the Mohawk valley, 6 to 10 inches above the Trenton limestone, D. amplexicaule is seen acquiring the characters of "D. pristis Hall." This latter form consists of a flattened film. The thecal walls have undergone upward deflection and oblique truncation so that the outline of the species is characterized by the acute "denticles" of the older writers. These denticles vary in every degree with the varying condition and present an average type merely on account of the average of conditions and of polypary flexibility.

Frech again, citing it as the typical form of Lapworth's subgenus Glyptograptus, terms it a younger mutation of D. pristis and also Hall, in the first description of the form, put cf. D. foliaceus Murchison under the headline, thereby indicating his belief of the possible identity of the two.

After a comparison of large suites of this type, obtained in the Trenton limestone at the two above mentioned localities with the shale varieties of

D. foliaceus and the observation of the occurrence of great numbers of specimens bearing the same character in separate shale horizons, the writer has not been able to come to the view that this form should be brought as a mutation under D. foliaceus, still less that it should be united with one of the varieties of D. foliaceus, as p. e. D. foliaceus var. incisus. From the latter it clearly differs in the much closer arrangement of the thecae (13–14 in 10 as against 8–9). In this regard it stands much nearer to D. foliaceus var. acutus with 12 to 13 thecae in the same space, to which variety it also is nearest related by the outline and dimensions of the rhabdosome and form of thecae in compressed state; but from which it still differs in not showing any sutural groove on the lateral face and possessing the concavo-convex section of the rhabdosome and curvature of the thecae towards the reverse side. This latter peculiarity, for which an explanation has been suggested on p. 98, it has in common with Climacograptus typicalis. As long as this feature has not been observed in D. foliaceus and its varieties, it seems to serve better the purposes of taxonomy to keep this form under a separate specific designation.

There exists considerable variation in the width of the rhabdosomes of the limestone material as a comparison of figures 302 and 304 will prove. The virgella and lateral spines are but weakly developed.

The appearance of the shale specimens is best illustrated by the material from Bakers falls, where they occur in surprising multitude, clearly forming a distinct zone of more than 50 feet thickness. The rhabdosomes are all preserved in a whitish Gümbelitlike substance and extremely compressed. They are mostly of the rugosus facies and present a striking appearance by the uniformity of their widths, the small, closely arranged "denticles" and broad unindented middle part [*see* 305], the little development of appendages of the sicular end and the absence of a free nemacaulus, by all of which characters they are easily distinguished from the varieties of D. foliaceus in like shale preservation. There are forms in the succeeding formations (Utica and Lorraine), which possess

similar characters and have frequently been identified with D. amplexicaulis and which quite surely have descended from this form.

Only few of these shale specimens, as that reproduced in plate 25, figure 12, will exhibit the characteristic imbricating of the thecae along the median line.

a Diplograptus amplexicaulis var. pertenuis nov.

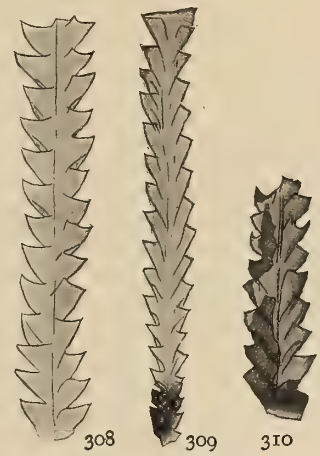
Plate 25, figures 14–16

Diplograptus amplexicaule Whitfield. U. S. Geog. Sur. West 100th Merid. Wheeler's Rep't. v. 4, Pal. 1877. p.19

Diplograptus amplexicaulis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.533ff

Professor Whitfield in 1875 writes:

> Just south of Troy, in the shaly partings between layers of metamorphic limestone, I have found a species of Graptolite in great abundance undistinguishable from G. amplexicaule Hall, from the Trenton limestone of Herkimer county, N. Y. The same species was also found abundantly in the yard of the arsenal at Watervliet by Capt. C. E. Dutton, U. S. A.



308 309 310

Fig. 308–10 Diplograptus amplexicaulis var. pertenuis nov. The originals of figures 308 and 310 are from Ruscher's quarry, Troy; that of figure 309 is from Lansingburg. x 5

The present writer has afterwards found the same form in numerous localities in the region indicated by Whitfield, associated with other Trenton forms. In most localities as at Watervliet, it is the only graptolite observed and completely fills the rock there; at the power house in Lansingburg it is equally common in one layer and there associated with a transitional fauna.

After more thorough comparison of the Trenton limestone specimens and those from the shales of the D. amplexicaulis zone, it has been found that while the latter exactly agree in form and closeness of arrangement of thecae with the Trenton limestone types of the species, they are distinctly and uniformly narrower. It is true, there are limestone specimens, equally narrow as that reproduced in figure 304, but they are extremes while the

shale specimens from Watervliet and Troy are all uniformly narrow, and compressed specimens would naturally be wider than the uncompressed Trenton limestone material, as the shale specimens of D. amplexicaulis from the Bakers falls indeed are. Hall's original drawings [v. 1] seem to represent equally narrow and slender specimens, but they are taken from the impressions left in the limestone by the broken-out rhabdosomes. Partly pyritized specimens from Watervliet show distinctly the imbricating thecae and the section characteristic of D. amplexicaulis, supporting thereby the reference of this material to the latter species. But the uniformity of thinness in the rhabdosomes and the distribution throughout a distinct horizon demand the recognition of our form as a type of varietal rank.

Description. The rhabdosomes are long (37+ mm) and very slender (usual width 1.2 mm, maximum width 1.4 mm) with concavo-convex section (?); without any free nemacauli. Virgella and lateral spines, if present, very inconspicuous. The thecal partitions distinctly shown on lateral sides, sutural grooves lacking. Thecae numbering 13 to 14 in 10 mm (32–34 to the inch), overlapping about one third their length, inclined 30 to 40°; with straight to slightly sigmoidal outer margin (concave proximally, straight to slightly convex distally) and straight aperture.

Position and localities. In the shale at the power house at Lansingburg, at Watervliet and various outcrops at South Troy (Brothers quarry, Ruscher's quarry, etc.), probably of Middle and Upper Trenton age.

Remarks. The specimens from the power house at Lansingburg had been originally [1901] identified by the writer with D. angustifolius; though in some of the preservation states of the thecae suggesting that species, they differ from it in widening much more gradually and growing to greater length with relatively smaller width.

Diplograptus (Glyptograptus) angustifolius (Hall)

Plate 25, figures 19, 20

Graptolithus angustifolius Hall. Pal. N. Y. 1859. 3:515, figure

Graptolithus angustifolius Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p.59, figure

Diplograptus angustifolius Nicholson. Geol. Soc. Quar. Jour. 1868. p.525, pl. 19, fig. 8, 9

Diplograptus angustifolius Lapworth. Cat. West. Scott. Foss. 1876. pl. 2, fig. 35

Diplograptus angustifolius Lapworth. Belfast Nat. Field Club. Rep't & Proc. Apx. 1877. v. 1, pt 4, p.132, pl. 6, fig. 11

Diplograptus angustifolius Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:21

Diplograptus angustifolius Walcott. Alb. Inst. Trans. v. 10. 1881. (Advance sheets, 1879. p.34)

Diplograptus angustifolius Lapworth. Geol. Sur. Can. Rep't. Ser. 2. 1886. 2:22D

Diplograptus angustifolius Lapworth. Science. 1887. 9:320

Diplograptus angustifolius ? Ami. Geol. Sur. Can. Rep't. Ser. 2. 1889. v. 3, pt 2, p.116K

Diplograptus angustifolius Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Diplograptus angustifolius Barrois. Ann. Soc. Géol. du Nord. 1892. 20:145

Diplograptus angustifolius Gurley. Jour. Geol. 1896. 4:298

Diplograptus angustifolius Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.541ff

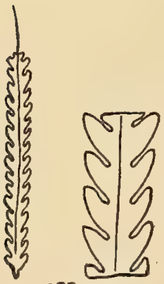
Diplograptus angustifolius Fearnsides. Section C, Belfast. 1902. Separates, p.1

Diplograptus angustifolius Weller. Geol. Sur. N. J. Pal. 1902. 3:52

Diplograptus cf. angustifolius Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33

Description. Synrhabdosome not observed. Rhabdosomes small (maximum length observed 27 mm), of uniform width, the full width being attained within 5 mm and amounting to 1.2 to 1.5 mm. Sicula not observed, sicular end furnished with a short virgella and two lateral spines, which are so thin that they are observed with difficulty. Nemacaulus also very delicate and hairlike, though obtaining a length equal to that of the rhabdosome. Thecae closely arranged, numbering 11 to 14 in 10 mm (28–34 to the inch), inclined at 30°, overlapping not quite one third of their length, the free ventral margin curved, concave below and very convex above. The apertural margin horizontal, in flattened specimens mostly more or less convex.

Position and localities. Common in some layers at the Normanskill (Kenwood) and at Glenmont near Albany, at Mt Moreno near Hudson, Stockport, Columbia co., Lansingburg, Rensselaer co. and other outcrops of the Normanskill shale. It has further been recognized by Lapworth in beds of Kicking Horse (Wapta) Pass (Rocky mountains of Canada), which are considered as of somewhat older age than the Normanskill shale; and by the writer in collections of probably like age from Silver Peak Quadrangle, Nevada. Gurley has found it in shales of Normanskill age from Arkansas. Ami has doubtfully referred forms from the neighborhood of Quebec to D. angustifolius and the present writer identified it in shales from New Jersey. In Great Britain, Lapworth has recorded it as one of the forms of the Glenkiln shales. D. angustifolius had hence a very wide distribution and was common to both the Atlantic and Pacific basins.


311


312


313


314

Fig. 311–14 Diplograptus angustifolius (Hall). Fig. 311 Copies of Hall's original figures. Fig. 312 Sicular extremity of a rhabdosome x 7. Fig. 313 Portion of a typical rhabdosome from Glenmont. Fig. 314 Specimen from Lansingburg, N. Y. x 5

I am not aware that it rises here above the Normanskill shale.

Remarks. Hall says of this species: "The form and proportions of these denticles are different from those of any species of graptolite in the collections from these shales, and often more resembling the minute denticulations on the fronds of fossil ferns than those of the graptolites."

This peculiar form of the thecae which is well reproduced in the original drawings [*see* text fig. 311] and is very characteristic of the species, is largely due to the deep excavation of the outer wall of the proximal part of the thecae and the resulting entering of thin shale films between this excavated part of the theca and the preceding theca, whereby the thecae

apparently become widely separated. In this excavation of the thecae it much resembles D. foliaceus var. acutus, with which it has also the number of thecae in a certain space in common. Its smaller and more nearly uniform width and the mostly convex aperture permit, however, of easy separation from that form, though a close relationship between the two is very probable.

Another species, which it approaches in the form of its thecae is D. euglyphus; which has a like deep excavation of the proximal part of the theca. From this again it can be distinguished by the different number of thecae in a certain space, D. euglyphus having a much looser arrangement of the thecae.

Diplograptus (Glyptograptus) euglyphus Lapworth

Plate 25, figures 21–23

Diplograptus dentatus (Brongniart) Lapworth. Belfast Nat. Field Club Rep't & Proc. v. 1. pt 4, apx. 1877, p.132. pl. 6, fig. 13

Diplograptus dentatus Lapworth. Geol. Soc. Quar. Jour. 1878. v. 34

Diplograptus dentatus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1879. 4:424

Diplograptus (Glyptograptus) euglyphus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:166, pl. 4, fig. 14a–e

Diplograptus euglyphus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 6:21

Diplograptus euglyphus Lapworth. Can. Geol. Sur. Rep't, 1887–88, 1889. Ser. 2. v. 3, pt 1, p.95 B

Diplograptus euglyphus Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:177ff

Diplograptus euglyphus Gurley. Jour. Geol. 1896. 4:298

Description. Synrhabdosome not observed. Rhabdosome long and narrow (40+ mm long and 1.4 mm–2.2 mm wide in mature parts), of uniform width (attaining its full width within 5 mm–10 mm). Sicular extremity furnished with minute virgella and rarely two thin curved lateral spines. Sicula not observed. Nemacaulus very thin, but attaining considerable length. Thecae numbering 7 to 9 in 10 mm (18–22 to the inch),

overlapping less than one third of length, inclined at an angle of about 40°; proximal part of outer wall excavated, distal part of outer edge very convex, aperture vertical to axis of theca, apertural margin concave. Interthecal excavation deep (nearly two fifths of width) and as long as free part of theca.

Formation and localities. Lapworth has described this species as one of the forms of the British Glenkiln beds and later on recognized it in collections from Dease river in British Columbia and various places in Quebec (Griffin Cove, Little Méchin river, Cove Fields, etc.). We have observed it in shales of the Normanskill zone from Glenmont, Albany co., Mt Moreno, near Hudson (where it is very common in one layer) and Speigletown. Lapworth's manuscript report does not record it from Stockport, Columbia co. We have also observed specimens which though badly compressed and extenuated, quite evidently belong to this type, in collections from Silver Peak Quadrangle, Nevada. The range of this form may begin below the Normanskill shale (at Dease river), and extend through the same into the Upper Dicellograptus zone (Cove Fields).

315 316

Fig. 315, 316 Diplograptus euglyphus Lapworth. Portions of rhabdosomes. x 5

Remarks. This species is easily recognized by its very long slender form and the wide intervals between the thecae. The latter are only to a small part due to a smaller overlap of the thecae and mostly to the deep excavation of the outer wall in the proximal part [*see* text fig. 315], which allows the shale to enter between the thecae and produces a concave outline of the proximal part of the theca. Also the convex outline of the distal part of the theca and the concave apertural margin are characteristic features of D. euglyphus.

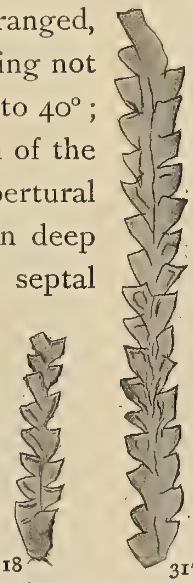
Lapworth states the form to be destitute of lateral spines, but in one of our specimens from Mt Moreno two very thin, curved spines are observable.

a **Diplograptus euglyphus** Lapworth var. **pygmaeus** nov.

Plate 25, figure 24

Description. Synrhabdosome attaining a diameter of 40+ mm and composed of 9+ rhabdosomes. Rhabdosome small (average length 10 mm, maximum length observed 21 mm), narrow (width usually but .9 mm, rising to 1.4 mm), of uniform width. Sicular extremity furnished with short, thin virgella and two equally unconspicuous lateral spines. Sicula not observed. Nemacaulus thin, rarely protruding from antisicular end and then but for a very short distance. Thecae very closely arranged, numbering 14 to 15 in 10 mm (34–38 to the inch), overlapping not quite one third of their length, inclined at an angle of 30° to 40°; outer margin first straight or slightly concave (by depression of the wall), and then convex; aperture normal to axis of theca, apertural margin straight to slightly concave. Interthecal excavation deep (two fifths of width) and half as long as denticle. No septal grooves observed.

Position and locality. This species was found to be very common in a layer in the Normanskill shale at the power house north of Lansingburg, Rensselaer co., N. Y.



318 317

Fig. 317, 318 Diplograptus euglyphus var. pygmaeus. Fig. 317 Portion of typical rhabdosome. Fig. 318 Young rhabdosome. x 5

Remarks. The present type is in most characters a smaller edition of D. euglyphus, with which it has the outline of the thecae in common. From other small forms it is easily distinguished by the combination of the shape of the thecae and their close arrangement. Only one fragmentary synrhabdosome [pl. 25, fig. 24] was observed. Though this variety has been found in but one layer, it occurs there to almost the exclusion of other forms (Climacogr. parvus and Diplogr. foliaceus the only other associates) and with great uniformity of characters.

The absence of free nemacauli is a noteworthy feature.

Diplograptus peosta Hall

Plate 25, figure 17

Graptolithus pristis (parte) Hall. Pal. N. Y. 1847. 1:72, fig. 1f, 1g

Graptolithus (Diplograptus) peosta Hall. Sup't Geol. Sur. Wis. Rep't. 1861. p.17

Diplograptus peosta Hall. Geol. Wis. 1862. 1:430

cf. Diplograptus amplexicaulis James. Amer. Geol. 1889. 4:237

cf. Diplograptus amplexicaule Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Diplograptus peosta Gurley. Jour. Geol. 1896. 4:298

Diplograptus peosta Whitfield. Amer. Mus. Nat. Hist. Mem. 2. 1895. p.47, pl. 5, fig. 12

cf. Diplograptus pristis Winchell & Schuchert. Geol. Minn. v. 3, pt 1, Pal. 1897. p.81, fig. 2

Diplograptus amplexicaulis Whitfield & Hovey (parte). Amer. Mus. Nat. Hist. Bul. v. 11, pt 1. 1898. p.20–21

Diplograptus amplexicaulis Ruedemann (parte). N. Y. State Mus. Bul. 42. 1901. p.561

Hall's original description of this species is:

Stipe (simple ?) robust, rounded on the surface, with section broad oval; very gradually widening from base, having a width of about $^{8}/_{100}$ inch; cellules narrow elongate, about 26 in the space of an inch; length about three and a half times the width of the cell, the free portion being about one third the length; inclined to the axis at an angle of about 35°; extremities of the cells truncate, the apertures somewhat quadrangular and rounded on the sides. Cell partitions strong and well defined, reaching nearly to the centre of the stipe in its lower part, leaving a very narrow space for the common body, which becomes wider above. Surface transversely striated or wrinkled.

Geological formation and locality. In the shales of the Hudson River group in Wisconsin, Iowa and Illinois.

We reproduce here a camera drawing of a plastically preserved specimen (internal cast without periderm) from Maquoketa creek, which is contained in the Hall collection in the American Museum of Natural History and labeled there as Hall's type of D. peosta. It well bears out in its characters and dimensions Hall's careful description. Besides I have before me specimens in the identical state of preservation and from a like calcareous shale of the Diplograptus bed in Graf, Iowa, and many others in com-

pressed state from the adjoining strata [nos. 11 and 13] of the same locality; and still others from the same horizon in Granger, Minn. and from the Triplecia bed [no. 10] near Wyckoff, Minn. All of these were kindly furnished by Professor Sardeson.

All these specimens agree without the least variation. From them the following data, supplementary to Hall's description can be gathered:

The rhabdosomes are throughout of small size (the greatest length observed in an incomplete specimen being only 20.5 mm and the majority not attaining more than 14 mm), and small width (Hall's type 2.6 mm, the majority not over 2 mm) this width being attained very gradually, while the sicular end is already 1.4 mm wide, so that the rhabdosome gives the impression of being of uniform width. The section of the rhabdosome is, as described by Hall, broad oval and both lateral sides are convex. The sicular extremity is rounded, furnished with a minute virgella and two short lateral spines. Siculae extremely common in some of the beds, small (1.6 mm), slender, with straight transverse aperture, a short rodlike virgella and small opposite lappet or mucro. Thecae numbering 11 to 13 in 10 mm (28–32 to the inch),[1] inclined at an angle of 30° to 40°, imbricated on the median line; overlapping two thirds their length; four times as long as wide; of subrectangular section; with rounded sides. Aperture normal on axis of theca.

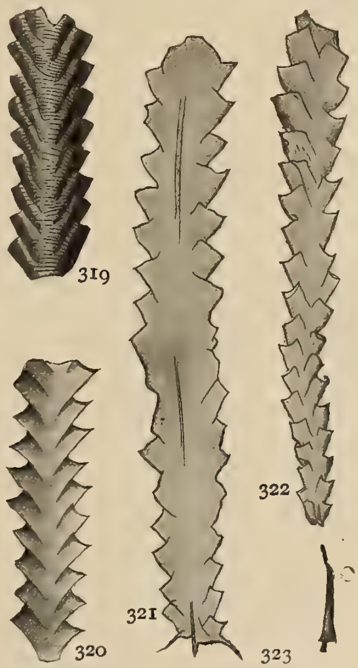


Fig. 319-22 Diplograptus peosta (Hall). Fig. 319 Hall's type specimen, preserved in relief. Fig. 321, 322 Flattened specimens in calcareous shale, from Granger, Minn. Fig. 320 Original of Hall's figure of Gr. pristis [pl. 72, fig. 1f, 1g]. The original of this figure is from the Lorraine shale at Lorraine, N. Y. Fig. 323 Sicula, from Granger, Minn. x 5

Position and localities. This is the common Diplograptus of the "Dip-

[1] Hall gives 26 in the space of an inch, which is a little less than our specimens show, the New York type included, which has nearly 30 in the space of an inch. Hall's smaller figure is undoubtedly due to the inability of obtaining camera drawings at the time.

lograptus shale" [Sardeson] of the Maquoketa beds in Minnesota, Wisconsin and Iowa. It also occurs, though rarely, in the Lorraine beds of New York and Hall's type of D. pristis, v. 1, pl. 72, fig. 1f, 1g [*see* text figure 319] from the "Hudson River group" at Lorraine presents all the characteristic features of this species.

Remarks. D. peosta is in its general habit and the form of the thecae a smaller D. amplexicaulis but attaining neither the length nor width of that species and differing in the form of its cross-section; while both have in common the alternate imbrication of the thecae on the lateral sides, and the closeness of their arrangement. The Lorraine specimens have as a rule been identified with D. amplexicaulis,[1] and Hall's type of figures 1f and 1g is on exhibit as D. amplexicaulis in the American Museum of Natural History. From the equally narrow D. amplexicaulis var. pertenuis here described, it differs in the much smaller length of the rhabdosome and the somewhat wider arrangement of the thecae.

Since Hall never figured his species[2] we can not wonder that in the west it has also failed to be recognized, and that the western paleontologists have identified it either with D. amplexicaulis (*see* James *loc. cit.*) or with D. pristis as Winchell and Schuchert have done, who cite the latter species from Granger, Minn., Cincinnati and Graf, Iowa, and reproduce Hall's figure 1a, which represents an equally small Lorraine mutation of D. foliaceus.

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[1] J. T. James records D. amplexicaulis from the Maquoketa shale [Amer. Geol. 4: 237]; Walcott mentions it as being found in the upper part of the Lorraine section [1890, p.339] and Whitfield and Hovey enumerate in their type catalogue [Amer. Mus. Nat. Hist. Bul. 1898, v. 11, pt 1, p.20–21] as D. amplexicaulis a number of Hall's types of Graptolithus pristis of Pal. N. Y. v. 1 from Turin, Lorraine and Collinsville and the present writer has commented [N. Y. State Mus. Bul. 42, p.561] on the reappearance of D. amplexicaulis in the Lorraine formation.

[2] A figure of D. peosta was not published until 1895, when Whitfield figured the types of Hall's Wisconsin Report.

GLOSSOGRAPTUS Emmons

The writer has touched the history of this interesting genus in Memoir 7 in regard to species from the third Deepkill zone but since the latter are so indifferently preserved that no structural details can be ascertained, no contributions to the still very imperfect knowledge of its structure, were made. A splendidly preserved series of specimens of the genotype from the Normanskill shale at Glenmont near Albany and another series of a closely related form from the shales at Summit, Nev. have furnished a few of the desired facts.

Owing to the incomplete knowledge of its structure, the taxonomic position of the genus is still uncertain. It is currently assigned to the Diplograptidi, and has even been recently considered as a synonym of Diplograptus by Frech [1897, p.624] who divides that genus into a nonspinose and a spinose section.

The above-mentioned material shows that in the genotype the section of the rhabdosome was subrectangular, with each of the lateral faces raised somewhat, either rooflike, or winglike, along the median line at the base of the lateral row of spines, so that the section approached a hexagon (for this seems the only way of explaining aspects like that represented in plate 27, figure 3, where in an oblique view the row of lateral spines completely hides the apertural margins of the other side). There were two different sets of spines, as Lapworth has demonstrated before, one of paired apertural spines of the thecae and another of stronger and differently directed spines or spurs along the median line of the lateral faces. The latter were so arranged that only to every second theca corresponded one pair [*see* pl. 27, fig. 3 and text fig. 329, where the lateral spines of both sides are shown]. As a result of these different sets of spines the two aspects, the lateral and the ventral, are entirely different. In the former, only the widely separated, upward directed lateral spines are visible, in the latter the four times greater number of slightly reflexed apertural spines alone are exposed [*see* pl. 27, fig. 1]. It can, therefore, not be wondered at that the two aspects have been taken for different species to the present day, the

former corresponding to Graptolithus spinosus Hall, the latter to Glossograptus ciliatus Emmons. A large series of specimens, like that from Glenmont, will however always furnish a few which, as that represented in plate 27, figure 1, are so broken or twisted as to exhibit both aspects. In plate 27, figure 2 both sets of spines are seen overlapping on one side of the rhabdosome.

The writer has already, in an introductory chapter on the morphology of spines discussed the probable causal connection of the spines and the origin of the framework of the periderm. There is no doubt that in Glossograptus a strong retioloid framework existed though it is covered by a thick outer or epidermal layer and therefore only exposed in macerated specimens. This structure had been recognized by Gurley, as appears from a note on Glossograptus found in his manuscript.

NOTE. (July, 1895.) I have made a number of attempts to decipher the structure in *Glossograpsus*, but so far the specimens seen have not been good enough to figure. This much, however, may be safely asserted: The structure in general accords with that in the other retiolitoid genera; parietal ledges are certainly present and mouth ledges also. Whether the cross-section was quadrangular or hexagonal is not very much important, it being merely a question whether the *two* halves of the lateral surface meet at a decided angle; the whole lateral surface is rounded convex. A much more important point is the number and character of the virgulae. On this point the material affords no clue. I have never seen any indication of a second virgula, though from analogy it is *inquirenda*.

We reproduce here in plate 27, figure 3 and text figure 329, specimens in which the outwardly curving horizontal mouth ledges and the convex lateral ledges are distinctly shown and in plate 27, figure 5 part of a specimen in which the epidermis is entirely lost and a meshwork exhibited, which, to all appearances, is like that of the Retiolitidae. Besides this structure, the figured specimen possesses three well preserved threadlike axes, the middle one of which is stronger and straighter than the rest which are slightly undulating. In the great majority of specimens the middle axis alone is visible. This is evidently due to the fact that the rhabdosomes as a rule are resting on one of the frontal or lateral faces and that only in obliquely

compressed specimens, such as the figured one is, the other axes are occasionally exposed. It is therefore legitimate to conclude that there existed in G. ciliatus a main axis as in the Retiolitidae that corresponded to the nemacaulus of the Diplograptidae [with included virgula]; and also several lateral axes. There are no lateral axes of any kind known in the Diplograptidae and the presence of such in Glossograptus will further support the exclusion of this genus from that family. In regard to the Retiolitidae Tullberg, Törnquist and Holm have demonstrated the presence of a straight main axis and of an opposite zigzag shaped secondary one; while Wiman [1895, p.42] has found that in Retiolites nassa [*see* text fig. 453] the rhabdosome is supported, aside from the nemacaulus, by four "Hauptleisten" running along the four margins of the prism. Since the thecae occupy the full width of the frontal sides, these "Hauptleisten" must be composed of the lateral ledges of the thecal apertures and of ledges bounding the ventral faces of the thecae [*see* Wiman's fig. 7]. Retiolites nassa has the thecae of a Climacograptus (and has for this reason been made the type of a new genus, Gothograptus, by Frech) while our form has those of a Diplograptus. Taking proper notice of this difference, it is to be expected that in Glossograptus the sections of the "Hauptleisten," consisting of the edges of the ventral faces of the thecae are reduced to almost *nihil* and the lateral ledges of the apertures alone compose the "Hauptleisten," which fact is apparent in plate 27, figure 3. There must further be found in Glossograptus altogether four vertical main ledges besides the nemacaulus, two bounding either row of thecae. These can indeed be made out in the figured specimen [pl. 27, fig. 5], since its margins have also the character of stronger longitudinal fibers. Of these that on the left hand side is distinctly composed of sections of ledges, evidently the lateral ledges of apertures.

The combined presence of a retioloid layer and of four main ledges warrant the translation of Glossograptus from the Diplograptidae to the Retiolitidae, though Glossograptus evidently partakes of the nature of a transitional form between the two on account of its strong periderm. One

might say that it has still the outside appearance of a diplograptid, but the inner structure of a retiolitid. But the difference is quite probably only one of grade of reduction of the outer layer of the periderm and the latter may have persisted as a thin membrane also in Retiolites and Gothograptus. At least this is suggested by Wiman's statement [*ibid.* p.41] that in Gothograptus nassa small lappets are observed which may be the remains of a membrane that filled the meshes. Glossograptus quadrimucronatus probably represents a stage with still stronger outer layer and less developed retioloid second layer.

The genotype is G. ciliatus Emmons. This contains, as has been mentioned above, Grapt. spinosus Hall as a synonym. There is no doubt in my mind, that G. setaceus Emmons, a form of which neither locality nor formation is given and which is insufficiently described from a fragment, that was "evidently injured" should be considered as another synonym [*see* text fig. 325].

Diplograptus ciliatus Emmons from Augusta county, Virginia, is clearly also a Glossograptus. Gurley has in recognition of this fact, and since the name G. ciliatus is preoccupied, proposed the name G. arthracanthus for the species [1896, p.78]. The peculiarities of this species are seen in the spines which according to Emmons are "bulbous, and jointed or transversely marked" and in the character of the "denticles," of which Emmons states, "serrations unequal, the intervening smaller serrations rounded, the larger prolonged and run into the base of the ciliae" [*see* text fig. 327]. The latter duplication of the denticles has been explained by Gurley, as being probably due to "a slightly oblique pressure causing the lower lateroventral margin of the polypary to extend beyond the upper lateroventral margin of the same, in such a manner that the corners of the thecal mouths alternate." Likewise are the bulbous and jointed character of the spines, from which Gurley has derived the new name for the species, in all likelihood due to the preservation of the specimen. I have observed like bulbous ends of spines in G. ciliatus [*see* pl. 26, fig. 8] and in other spinose graptolites and consider them as caused by

the oblique breaking of the shale through a point of the spine where it was slightly bent sidewise, the combined oblique fracture and sidewise bending producing a wider, club-shaped section of the spine. Since in G. ciliatus mut. horridus only a fraction of the spines of a few rhabdosomes are bulbous, they can not be considered as constituting a specific character. Furthermore, they are shorter than the other spines and obviously incomplete. There has further in no other species of Glossograptus been observed anything pointing to a tendency of jointing or segmentation of the spines, while it is easily conceived that the fine, more or less parallel fractures, which transect all graptolites in shale, could properly directed, give the spines a jointed appearance. But with the explanation of the above-mentioned peculiarities of this species as freaks of preservation, there is nothing left to distinguish it by and it becomes more than probable that it is another synonym of G. ciliatus.

In G. arthracanthus, as well as in G. setaceus the spines are straight and could therefore be thought to be distinguished by this character from the reflexed spines of G. ciliatus. But they are clearly incompletely preserved in the type specimens of both species and correspond only to the straight proximal parts of the thecal spines or to the straight spines of the median line of the lateral faces.

For reasons given in their descriptions and on p.85 we have also referred Diplograptus quadrimucronatus and D. whitfieldi to this genus. The former has been made by Lapworth the type of a new subgenus (Orthograptus) which, then, may also become available as a subdivision of Glossograptus.

Glossograptus ciliatus Emmons

Plate 26, figures 1–5; plate 27, figures 1–4

Glossograptus ciliatus Emmons. Am. Geol. pt 2. 1856. p.108; pl. 1, fig. 25

Glossograptus setaceus Emmons. *Ibid.* p.236; pl. 1, fig. 20

Graptolithus spinulosus Hall. Pal. N. Y. 1859. 3:507 (fig.)

Graptolithus spinulosus Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't 1860. p.60

Glossograptus ciliatus Hopkinson & Lapworth. Geol. Soc. Quar. Jour. 1875. 31:659; pl. 34, fig. 7

Glossograptus spinulosus Lapworth. Ann. Mag. Nat. Hist. 1880. 5:283

Diplograptus ciliatus Walcott. Alb. Inst. Trans. v. 10, 1881. (Advance sheet. 1879. p.34)

Diplograptus spinulosus Walcott. *Ibid.* p.35

Glossograptus ciliatus Lapworth. Roy. Soc. Can. Trans. 1887. v. 5, sec. 4, p.184

Glossograptus ciliatus Lapworth. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 1, p.95 B

Glossograptus ciliatus Ami. Geol. Sur. Can. Rep't. Ser. 2. 1889. v. 3, pt 2, p.117 K

Glossograptus spinulosus Dodge. Am. Jour. Sci. 1890. 40:153

Diplograptus spinulosus Walcott. Geol. Soc. Bul. 1890. 1:339

Glossograptus ciliatus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:404 f

Glossograptus spinulosus Gurley. *Ibid.* p.411

Glossograptus ciliatus Gurley. Jour. Geol. 1896. 4:299

Glossograptus spinulosus Gurley. *Ibid.* p.299

Description. Synrhabdosome not observed. Rhabdosome prismatic with subhexagonal section, attaining a length of 25 + mm [*see* "Remarks"] and a width of 1.6 mm on the frontal sides and the double width on the lateral faces (often double that width again in obliquely compressed specimens, *see* below). Sicular extremity rounded, furnished with four short, straight sicular spines (1.2 mm long) which are directed downward and two longer horizontal lateral spines. Lateral faces smooth, bearing along the median line a row of straight spines (1.4 mm long), which are directed upward at an angle of 40° and correspond to every second theca. Sicula large (3.3 mm), plump, with four apertural spines that are connected by a strong apertural ring [fig. 331]. Thecae broad and low (ratio 2:1), rectangular in section, inclined at an angle of 30°, overlapping three fourths their length, numbering 11 in 10 mm with little variation. Apertures rectangular, lower and upper margins straight, lateral margins concave; each protected by two long curved spines (3 mm long, but 2 mm of which are

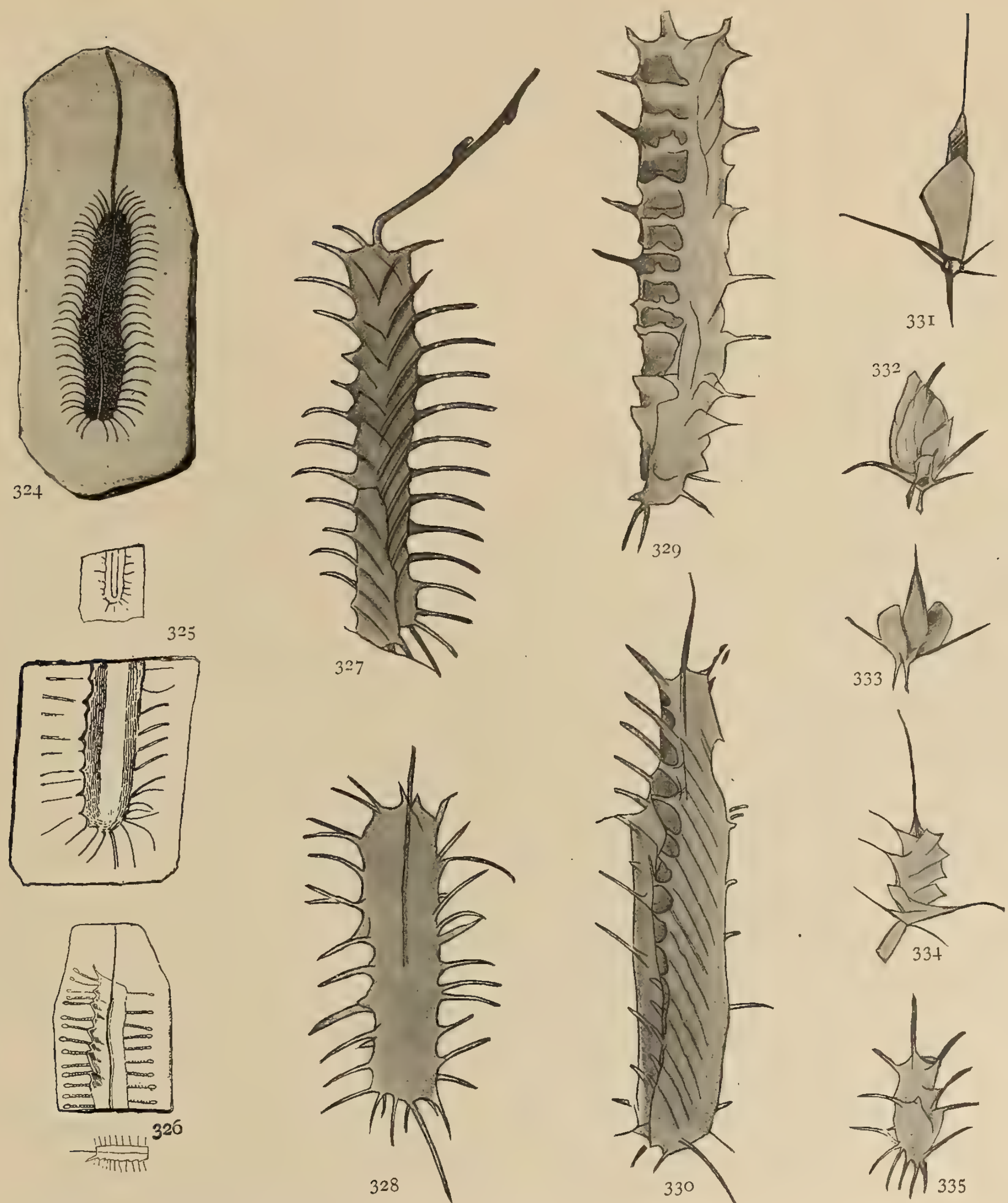


Fig. 324–35 Glossograptus ciliatus Emmons. Fig. 324 Copy of Emmons's original figure (enlargement) of the species. Fig. 325 Copy of Emmons's figure of G. setaceus. Fig. 326 Copy of Emmons's figure of Diplograpsus ciliatus. Fig. 327 Fragment of rhabdosome showing two rows of apertural spines. Fig. 328 Young rhabdosome showing spines of sicular extremity and double apertural spines. Fig. 329, 330 Obliquely compressed specimens showing the apertures. Fig. 331–35 Characteristic aspects of growth stages. Figure 333 shows the sicula and two primary thecae. The originals of figures 327 to 335 come from Glenmont, N. Y. All are enlarged x 5, except figure 331 which is enlarged x 7. *See also* text figures 8, 31, 32

mostly preserved), which proceed from the middle of the horizontal "mouth-ledges." Nemacaulus thin (.1 mm), attaining great length (30 mm) and frequently inflated into a fusiform vesicle [*see* text fig. 31, 32].

Position and locality. Emmons's type came from the "dark colored shales of Columbia county, N. Y.," Hall's type of Grapt. setaceus from the Normanskill shale at the Normanskill near Albany. We have before us a splendid series of specimens from the same shale at Glenmont, south of Albany. It likewise occurs in other outcrops of the same horizon in the slate belt of New York, as at Mt Moreno near Hudson, at the Kinderhook creek, etc. The collection of Normanskill shale graptolites from Alabama contains it in great number and large specimens [*see* below]. Lapworth has recorded it from Long Point, St Anne river, Quebec, where it is the only graptolite occurring and from the beds at Kicking Horse pass and Dease river, British Columbia, which are considered by that author as older than the Normanskill shale and referred to the Chazy by Gurley [1896, p.298]. Gurley has further recognized it in beds of Normanskill age in Arkansas and referred to it, following Lapworth's manuscript report, specimens from shales of Summit, Nev., probably of Beekmantown age [*see* "Remarks"]. Dodge has listed it also from Maine and Hopkinson and Lapworth have identified with G. ciliatus a specimen obtained in the St David's beds (Upper Arenig) in 1880 and Lapworth [1880, p.276] also cites it from Tyobry in N. Wales. It is also probable that the Glossograptus sp. cited by Tullberg as characterizing two zones and a subzone of the Middle graptolite shales of Scania belongs here. G. ciliatus seems in this State to be restricted to the Normanskill shale though in other regions as in Great Britain and British Columbia, it may have appeared earlier.

Remarks. For reasons given in the generic description we have here united Hall's species Grapt. spinulosus as a synonym with G. ciliatus, as representing but another aspect of the latter. Emmons's G. setaceus, which is described in the same publication with G. ciliatus without locality is clearly but a fragment of the sicular end in

the same aspect as Grapt. spinulosus, i. e. exhibiting but the straight spines of the lateral faces.[1]

A characteristic feature of this type of graptolite is seen in the earlier growth stages. They are among the most striking objects of the Normanskill shale [text fig. 331–35] and differ by their pear-shaped outline and multispinose sicular extremity from the early stages of all other associates. The plump form is partly due to the wide sicula and still more to the broad stout shape of the first thecae. Each of the latter is protected by a long needlelike straight spine, projecting obliquely upward from the middle of the outer margin [*see* fig. 22], but apparently taking its origin from the apertural margin of the sicula.

The specimens from the shales of Normanskill age in Alabama are distinguished by greater length (40+mm) and greater width (that of lateral face = 2 mm) from the New York types, but do not seem to differ in other respects and their thecae possess an equally close arrangement.

Glossograptus ciliatus Emmons mut. **horridus** nov.

Plate 26, figures 8, 9

A comparison of the specimens from Summit, Nev., referred by Lapworth and Gurley to G. ciliatus, with the typical material from the Normanskill shale of New York, brings out the existence of differences which are important enough to call for a separation of this western form as a mutation at least. The fact that the Nevada specimens occur in a faunule that has no species in common with the Normanskill fauna and represents an earlier zone, renders it already probable that the two forms are different.

In G. ciliatus mut. horridus, as we will call this mutation, both the apertural and lateral spines are fully twice as long as in the typical

[1] In the light of the facts obtained from the finely preserved Normanskill shale specimens of Glossograptus, it becomes also very doubtful whether the two species, G. echinatus and G. hystrix, described by the writer in Memoir 7 from the third Deepkill zone, are specifically distinct, for their difference is mainly of the same nature as that between G. ciliatus and G. setaceus.

G. ciliatus [*comp.* pl. 26, fig. 4 and fig. 8]; consequently they will often both appear in the same view of a specimen and produce a thick crown of spines. While in G. ciliatus the spines of the lateral faces are rather stout, spurlike, straight and diverted obliquely upward, they are here thin, hairlike and horizontal in direction [*see* pl. 26, fig. 9]. The width and length of the rhabdosome seem to be the same as in the Normanskill types, but the sicular extremity is less rounded and the whole rhabdosome more gradually widening, hence the lateral margins never so strictly parallel as in G. ciliatus. The sicula and the characters of the thecae have not been observed.

Position and locality. This mutation is found in dark brown shales at Summit, Nev., where it is associated with Phyllogr. anna, Climacogr. caelatus, Cryptogr. tricornis and Caryocaris.

Glossograptus ciliatus Emmons var. **debilis** nov.

Plate 26, figures 6, 7

Description. Synrhabdosome not observed. Rhabdosome small (16+ mm long), narrow (width of side 1 mm), with parallel margins. Nemacaulus thin, protruding to length of rhabdosome. Sicular and antisicular extremities rounded. Spines as in G. ciliatus. Sicula not observed. Thecae very closely arranged (16–22 in 10 mm), shorter than in G. ciliatus, but apparently not differing in overlap and inclination.

Position and locality. In the Normanskill shale of Mt Moreno near Hudson.

Remarks. This variety covers in great number a layer at Mt Moreno. Its differences from the typical ciliatus, which consist in the smaller size and width and greatly closer arrangement of thecae, are uniform. These and the frequent irregular bendings of the rhabdosomes give the form the appearance of a weaker variety of G. ciliatus which lived under less favorable physical conditions. Held side by side with the sturdy specimens of G. ciliatus from Alabama, the contrast is still more striking.

Glossograptus (Orthograptus) quadrimucronatus (Hall)

See plate 26, figures 10–15; plate 27, figures 6, 7

Graptolites dentatus Vanuxem. Geol. N. Y. 3d Dist. 1842. p.57, fig. 2

Graptolites dentatus Emmons. Geol. N. Y. 2d Dist. 1842. p.279, fig. 2

Graptolites dentatus Hall. Geol. N. Y. 4th Dist. 1843. p.29

Graptolithus pristis (in part) Hall. Pal. N. Y. 1847. 1:265; pl. 57, fig. 1a–k

Graptolithus quadrimucronatus Hall. Can. Org. Rem. Dec. 2. 1865. p. 144; pl. 13, fig. 1–10

Diplograptus quadrimucronatus Nicholson. Geol. Mag. 1867. 4:111, pl. 7, fig. 1–8

Graptolithus quadrimucronatus Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. pl. 3, fig. 1–5

Diplograptus quadrimucronatus Lapworth. Geol. Mag. 1877. 6:133; pl. 6, fig. 20

Diplograptus quadrimucronatus Lapworth. Belfast Nat. Field Club. Rep't & Proc. v. 1. 1876. Apx. 1877. p. 133; pl. 6, fig. 20

Diplograptus quadrimucronatus Linnarsson. Sver. Geol. Und. Ser. C, no. 31. 1879. p.18

Diplograptus quadrimucronatus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:359

Diplograptus quadrimucronatus Tullberg. Sver. Geol. Und. Ser. C, no. 41. 1880. p.18

Graptolithus quadrimucronatus Walcott. Alb. Inst. Trans. v. 10. 1881. (Advance sheet, 1879. p.35)

Diplograptus quadrimucronatus Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p.18

Orthograptus amii Lapworth. Can. Sur. An. Rep't for 1887. p.15K, 24K

? Graptolithus quadrimucronatus White. U. S. Geog. Sur. West 100th Merid. Wheeler's Rep't. v. 4, Pal. 1877. p.65

Diplograptus pristis (Hall) Ruedemann. Am. Jour. Sci. Ser. 3. 1895. 49:453

Orthograptus quadrimucronatus Ami. Can. Record Sci. (1892–93). 1893. 5:180 ff, 234 ff

Diplograptus foliaceus (in part) Ruedemann. N. Y. State Geol. An. Rep't for 1894. 1895. pl. 1, fig. 1, 5, 8, 9; pl. 2, fig. 6; pl. 3, fig. 1–26

Diplograptus quadrimucronatus Gurley. Jour. Geol. 1896. 4:98, 298

Diplograptus pristis (Ruedemann) Wiman. Geol. Inst. Upsala. Bul. 5. 1895. p.69

Diplograptus pristis (Ruedemann) Tornquist. Zool. Centralbl. 1897. 4:4

Diplograptus aff. whitfieldi Roemer & Frech. Lethaea Pal. 1897. v. 1, pl. A, fig. 1b, 1c

Diplograptus foliaceus Ruedemann. Am. Nat. 1898. 32:6

Diplograptus quadrimucronatus et foliaceus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.528

Diplograptus foliaceus Ruedemann. N. Y. State Mus. Mem. 7. 1904. p.528, fig. 9

Orthograptus quadrimucronatus Ami. Geol. Sur. Can. Sum. Rep't for 1904. (1905) p.12

Diplograptus (Orthograptus) quadrimucronatus T. S. Hall. Geol. Sur. Victoria Rec. 1906. v. 1, pt 4, p.275; pl. 34, fig. 10, 11

Description. Entire colony forming a synrhabdosome which is composed of 30 or more sicula-bearing rhabdosomes. The latter stout and long, quadrilateral, the lateral and frontal sides of approximately equal width; the lateral faces plain, the frontal ones straight or very gradually increasing in width to 3 mm (indicating a width of 1.5 mm for one side, exclusive of the apertural spines); attaining a length of 60 mm and more in the largest fragments. Periderm consisting of a thick outer layer and a fibrous inner one [*see* "Remarks"]. Sicula stout, nearly 2 mm long, provided with a straight apertural margin and a distinct virgella. Thecae relatively broad and short, three times as long as wide, overlapping two thirds their length; forming an angle of 30°–32° with the axis, numbering 11 in the space of 10 mm at the sicular end and 10 at the antisicular end in the typical form. Each apertural angle produced into a mucronate spine which equals in length the width of the aperture and is rectangular on the axis of the theca. Nemacaulus thin and apparently little flexible, hence mostly missing; in some cases broad and expanded into a "vesicle."

Fig. 336 Glossograptus quadrimucronatus (Hall). Copy of one of Hall's original figures. *See also* text figure 9

Position and localities. Hall originally described Grapt. quadrimucronatus from the Utica shale at Lake St John, in the Province of Quebec, where it occurs in association with Leptogr. flaccidus

and Glossogr. ? eucharis. It is now known to be the most common biserrate graptolite of the Utica formation in Canada and in the belt girdling the Adirondacks. In the slate belt along the Hudson river a variety has been found in great numbers and exquisite preservation in the quarries at the Rural cemetery between Albany and Troy and another in the outcrops of the Utica formation to the north and south of this locality (as at the Normanskill above Normansville, at the penitentiary in Albany, Black creek near Voorheesville, etc.). In New York State it also enters the Lorraine formation and occurs, in the lowest part of the formation at least, in a well defined mutation but has as yet not been found below the Utica formation. In the west it appears to occur in a variety in the Utica shale at Cincinnati.

Ami states that it is the most common graptolite in the Utica shale of Canada and is found almost invariably in all collections from that formation. He records it from numerous localities of the Canadian belt of Utica strata, notably the neighborhood of Quebec, Montreal, and the north shore of Lake Huron, and besides from the basins of Lake St John and Ottawa. He does not cite it from the Lorraine beds.

The form from Belmont, Nev., identified by White [Wheeler's Rep't] with G. quadrimucronatus is, according to Gurley [1896, p.306], not identifiable.

In Great Britain it has been recognized by Nicholson in the shales at Dobbs Linn in Scotland and is recorded by Lapworth (1880, p.359) as occurring in the Pleurograptus-linearis zone which is the highest of the Lower Hartfell shales and also in the Tralodden beds in the Girvan district. In Scandinavia it is the characteristic form of a graptolite zone in the Trinucleus-beds of the Middle Graptolite shales in Scania.

T. S. Hall has this year also announced the occurrence of this species in the rocks of Victoria, Australia. It is distinguished there by the presence of four prominent spines at the level of about the seventh or eighth thecae, a feature which it has in common with Scottish and Irish forms.

Remarks. In his paper in the Report and Proceedings of the Belfast

Field Club, Lapworth stated his belief that this form is allied to Glossograptus but that the evidence at hand is not yet sufficient to justify its removal to that genus.

From Gurley's notes I learn that he has followed this suggestion of Lapworth and used the finely preserved material from the type locality of the species for an investigation of this important taxonomic problem, arriving at the following conclusion:

> Specimens from Lake St John show that the structure of the species has been entirely misapprehended, and that its affinities are retioloid rather than diplograptid. The thecal openings are bounded by continuous fibers (mouth ledge, etc.) and the lateral faces show (partly in one specimen, partly in another) the remains of a periderm, and the fibers when seen, correspond fully to the parietal ledges of Holm. The last show virgular connections in places and form on the lateral faces a network whose interstices are filled with a black carbonaceous matter, similar to the periderm found in Retiograptus geinitzianus. Indeed the structure is so like the latter genus that pending better material, it may be placed here though I incline to believe it belongs rather to some of the allied genera. In Retiograptus its most marked peculiarity is the great obliquity of the thecae to the virgula.

On specimens from the same locality, and others from outcrops in the Mohawk valley, I have been able to verify Gurley's observation as far as the mouth ledges and the ascending branches of the parietal ledges are concerned while the structure of the lateral faces is nearly always completely obscured by the thick covering periderm. In badly macerated examples, however, where the continuous periderm is lost, a fibrous layer is sometimes exposed. In one of the specimens, from the Utica shale of Dolgeville [*see* pl. 27, fig. 6], I have been able to make out, before I was aware of this view, two rows of meshes, one of which corresponds to a row of thecal apertures. This aspect as well as the smooth, flat, heavily covered lateral faces resembles more that of Retiograptus geinitzianus Hall, as described in this paper than of any other form. Since, however, it is shown here that Lasiograptus and Glossograptus also possess a similar system of fibers within their periderm, the question of the relationships of G. quadrimucronatus should be handled most cautiously

as long as only shale material is available. Lapworth further describes the Scottish and Irish representatives of the species as possessing lateral spurs at a short distance from the sicula [*see* text fig. 9]. These suggest homology to the rows of lateral spines of Glossograptus and it is therefore logical that this author points out the probable near relationship of Orthograptus quadrimucronatus to Glossograptus. It might here also be remarked that the broad smooth flat lateral faces of quadrimucronatus find their exact counterpart in those of Glossograptus.

On the whole, it seems that Frech's proceeding in separating the species of Diplograptus with spines from those without spines is correct and that the spinose species will all, in time, be found to have a similar structure as G. quadrimucronatus and be removed from the genus altogether.

The beautiful material from the Rural cemetery has permitted in many specimens a very clear observation of the youngest stages of the rhabdosome. In these [*see* pl. 27, fig. 8, 9] the sicula is seen to be provided with distinct growth-lines, the first theca to originate very near the distal end of the sicula, to grow forward as far as the apertural margin of the sicula and then to bend outward and finally backward. This genus shows hence the same remarkable reverse of the first theca, as Diplograptus and Climacograptus. Also the mode of budding and arrangement of the succeeding thecae are as far my observations go, the same as in Diplograptus. The first and second thecae bear instead of the two lateral spines of the apertures seen in the later thecae, but one frontal spine each. These two spines are, as in the Rural cemetery material, liable to grow out to immense size and to form with the equally growing virgella of the sicula a strong tridentate organ of defense [*see* text fig. 341]. Sometimes also the virgella fails to grow out and only the two thecal spurs appear on the sicular extremity of the rhabdosome, as in the specimen reproduced in text figure 340.

Hall remarks upon the great number and difference of the aspects offered by this species as follows:

The species under consideration, in its various aspects, illustrates more fully than any other which we have seen the effects of pressure in different directions.

These differences are to some extent illustrated by the figures here given, notably in the synrhabdosomes, though no attempt could be made to bring out by special figures these more accidental features. Some discrepancies in the descriptions which have been given of this species, are undoubtedly due to these greatly differing aspects. Thus Hall describes the thecae as consisting " of simple notches or transverse slits in the opposite sides, which are slightly indented in the noncelluliferous face" and though this is the most frequent aspect of the thecae, there are others from Lake St John which distinctly show the projecting thecae.

To this protean character of its aspects is also partly due the extended failure to recognize this form which is the most common and evidently also the most typical graptolite of the Utica shale in New York and Canada. The story of this failure is revealed by the before-given synonymy. Hall described the species in 1865 from the well-preserved material of Lake St John in Canada and cited this locality alone as its place of fossil occurrence. In 1847, in the first volume of the *Palaeontology of New York*, he had described under one caption, both the common graptolite from the Normanskill shale, Diplograptus foliaceus and G. quadrimucronatus, referring both to Hisinger's species Graptolithus pristis. Most of his drawings of that species belong to G. quadrimucronatus. The superior state of preservation of the rhabdosomes of the St John material to that from the Utica shale of New York accounts easily for his failure and that of all others, the present writer included, who have studied the New York collections, to properly identify this common fossil. While the occurrence of G. quadrimucronatus in the British beds had meanwhile been recognized by Nicholson and Lapworth and a Swedish horizon had received its name from it by Tullberg, Gurley cited still in 1896 G. quadrimucronatus from its Canadian locality only. When the present writer discovered whole colonies (synrhabdosomes) near Dolgeville and laid these before the venerable master of New York paleontology, they were unhesitatingly referred to Diplogr. pristis and, since the American "pristis" had meanwhile been claimed to be identical with D. foli-

aceus Murchison, described as belonging to the latter species. But the writer added in his drawings the apertural spines which, though rarely, were observed in some of the Dolgeville material. This gave Frech occasion to point out in the *Lethaea Palaeozoica* that the colonies could not belong to D. foliaceus, which is a spineless form and they were by him united provisionally with G. whitfieldi. Not until the splendidly preserved graptolites from the Utica shale of the Rural cemetery near Albany came into the writer's hands, did he become aware of the presence of this St John species in the Utica rocks of New York.

Ami, however, had before this recognized the wide distribution of G. quadrimucronatus in the Utica shale of Canada, as is evinced by his fossil lists.

There is no doubt that Vanuxem, Emmons and Hall had also this form before them, when they cited Graptolites "dentatus" as the most common and characteristic graptolite of the Utica shale of the Mohawk valley in their respective district reports. Of this fact we had an opportunity to convince ourselves by inspection of some of the old types of the First Geological Survey collection now in the American Museum of Natural History. One of these from the Utica shale of Oxtungo creek, in the Mohawk valley, is figured by Hall as D. pristis on plate 72, figure 1d.

That D. foliaceus to which the synrhabdosomes from the Utica shale had been first erroneously assigned, possesses colonies of the same complex structure, is shown by the synrhabdosomes figured in this volume.

The failure to recognize G. quadrimucronatus in the Utica shale of New York is due to still another circumstance, namely, to the fact that the specimens from the New York rocks in no case reach the large dimensions of the types from Lake St John and altogether represent a smaller variety and in the Lorraine beds a different mutation; they do not only differ in their general dimensions, but also in the number of thecae within a certain space; the Lake St John types possessing quite uniformly 22 to 23 thecae within an inch or 25 mm and those from the Utica shale of the Mohawk valley 26 to 28 thecae. In the Lorraine specimens this differ-

ence becomes still more pronounced (in one I counted 36 thecae in the same space) and the narrow long rhabdosome with its very closely arranged thecae presents an aspect quite different from that of the typical form.

These changes point evidently to racial degeneration preliminary to the extinction of the species occurring at the end of the Champlainic. Since they are also connected with areal separation, the forms should find recognition as subspecies.

The variety characteristic of our Utica shale I propose to term

Glossograptus quadrimucronatus (Hall) var. **approximatus** nov.

Plate 26, figures 10–15; plate 27, figures 6–7

This is the form whose synrhabdosomes have been found by the author near Dolgeville. It differs principally from the typical G. quadrimucronatus in the dimensions (average length and width of rhabdosome 40 mm and 2 mm respectively), the somewhat narrower sicular end and closer arrangement of thecae (10–11 in 10 mm or 26–28 in 1 inch). The mucros are less conspicuous than in the typical form but still very distinct. The nemacaulus is thicker and frequently of great length.

Fig. 337 Glossograptus quadrimucronatus var. approximatus nov. Portion of rhabdosome showing fibers in perisarc. x 5 (Comp. pl. 27, fig. 6)

Prof. Lapworth has in the description of Diplograptus foliaceus in his manuscript report commented on the fact that that species exhibits all variations from D. dentatus Brongniart to G. quadrimucronatus. He therefore apparently considers G. quadrimucronatus a derivative of D. foliaceus, a view which would seem to be supported by this variety, for the latter could as well be regarded as a variety of D. foliaceus with paired apertural mucros as one of G. quadrimucronatus. This is still more obviously true in regard to the next variety, which in outline of rhabdosome and form of thecae is nearest related to D. foliaceus var. acutus, but furnished with paired thecal spines that are even longer and more conspicuous than in the typical G. quadrimucronatus. Using the presence of these spines as the princi-

pal criterion of distinction between the two species, we have preferred to associate the present variety with G. quadrimucronatus.

Glossograptus quadrimucronatus (Hall) var. cornutus nov.

Plate 27, figures 8–10

The rhabdosomes of this variety are of medium size (average length 25 mm, rarely surpassing 30 mm, and width 2.5–3 mm), beginning with a rounded sicular extremity 1.2 mm wide; rapidly attaining the full width (in space of about 4 mm). Sicular extremity buttonlike and furnished with two long, hornlike curved lateral spines and a strong virgella, all of which show great individual differences in development. Nemacaulus very thin and hairlike. Test thick. Sicula 2 mm long. Thecae numbering 10 to 12 in 10 mm (25–30 in space of 1 inch), one third as wide as long, inclined 30° to the axis, overlapping one half their length. Aperture rectangular to axis, broad and slightly concave. Apertural spines as long as aperture, straight, and directed horizontally.

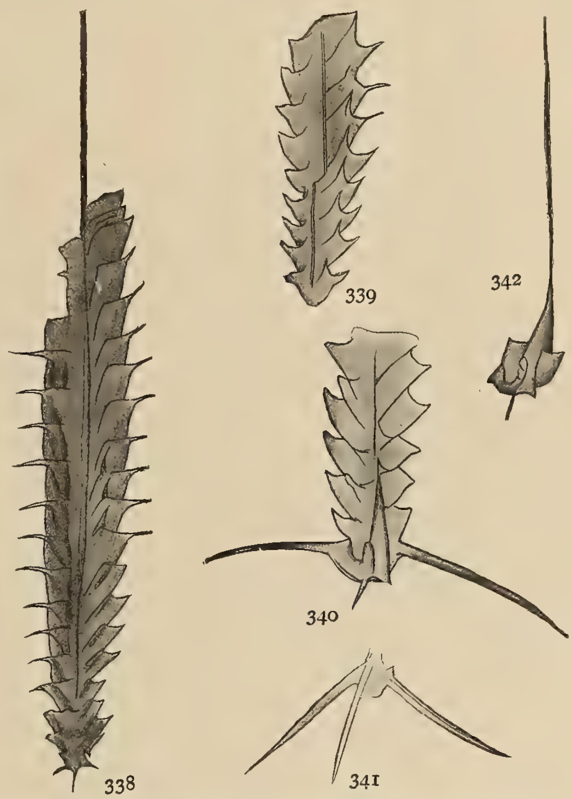


Fig. 338–42 Glossograptus quadrimucronatus var. cornutus nov. Fig. 338 Rhabdosome. Fig. 339 Portion of rhabdosome showing both apertural spines of thecae. Fig. 340 Sicular end, showing sicula, first theca and large lateral spines. Fig. 341 Sicular extremity with three large spines. Fig. 342 Growth stage of rhabdosome with three thecae. Figures 338, 339, 341 are enlarged x 5; figures 340, 342 x 7

This variety has been found only at the Rural cemetery near Albany, but there in great number and excellent preservation. Its most striking features are the long apertural spines and the strong, frequently curved lateral spines of the sicular end, in support of which the test of that whole part has become so much thickened that the extremity frequently stands out buttonlike. From

the typical G. quadrimucronatus this variety differs principally in the smaller overlap of the thecae which gives to the profile view the aspect of a Diplograptus foliaceus and the development of the lateral spines. No traces of the differentiation of the test into a continuous and a fibrous layer, observed in G. quadrimucronatus, have been noticed in this species, if not the presence of a solid rim of the aperture, connecting the two apertural spines is to be taken as indicating that structure. The nemacaulus is, in the great majority of the specimens, very thin, but in some it has been observed to expand into long fusiform "vesicles."

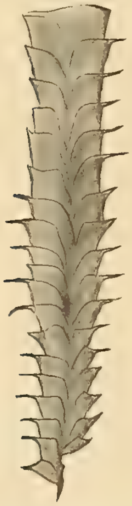


Fig. 343 Glossograptus quadrimucronatus var. postremus nov. Rhabdosome. Waterford, N. Y. x 5

Glossograptus quadrimucronatus (Hall) mut. **postremus** nov.

Plate 26, figure 16

The reduction in the width of the rhabdosomes and the close arrangement of the thecae — both resulting from a reduction in the size of the zooids and indicating a decadent condition — have gone still a step farther in the Lorraine mutation, which has been observed in the lower beds at Waterford, above Mechanicville, Frankfort, and in other places. The width is here reduced to 2 mm and the number of thecae has risen to 12 to 16 in 10 mm (30–40 in the inch).

Glossograptus whitfieldi (Hall)

Plate 26, figure 17

Graptolithus whitfieldi Hall. Pal. N. Y. 1859. 3:516, fig. 1

Graptolithus whitfieldi Hall. N. Y. State Cab. Nat. Hist. 13th Rep't. 1860. p.60, fig. 1

Graptolithus whitfieldi (in part) Hall. Can. Org. Rem. Dec. 2. 1865. p.31, fig. 29; p.36, fig. 31; non pl. B, fig. 6–11

Diplograpsus whitfieldi Nicholson. Geol. Mag. 1867. 4:111; pl. 7, fig. 4, 4a

Graptolithus whitfieldi Hall. N. Y. State Cab. Nat. Hist. 20th Rep't. 1868. p.199, fig. 31

Diplograptus whitfieldi Nicholson. Monogr. Brit. Grapt. 1872. p. 54, fig. 23; p.69, fig. 39b

Diplograptus whitfieldi Lapworth. Cat. West. Scott. Foss. 1876. pl. 2, fig. 45

Diplograptus whitfieldi Lapworth. Belfast Field Club. An. Rep't & Proc. Ser. 2, apx. 1877. v. 1, pt 4, p.134; pl. 6, fig. 21

Diplograptus whitfieldi Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheet. 1879. p.35)

Diplograptus whitfieldi Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 6:21

Diplograptus whitfieldi Lapworth. Roy. Soc. Can. Proc. & Trans. 1886. 4:184

Diplograptus whitfieldi Ami. Geol. Sur. Can. Rep't. Ser. 2. 1889. v. 3, pt 2, p.117K

Diplograptus whitfieldi Geinitz. Mitth. K. Min. Geol. praeh. Mus. Dresden. 1890. 9:35; pl. A, fig. 52

Diplograptus whitfieldi Gurley. Geol. Sur. Ark. Rep't. 1890. 3:411

Diplograptus whitfieldi Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Diplograptus whitfieldi Gurley. Jour. Geol. 1896. 4:298

Diplograptus whitfieldi Frech. Lethaea Pal. 1897. 1:631; non fig. 192

Diplograptus whitfieldi Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.497, 541

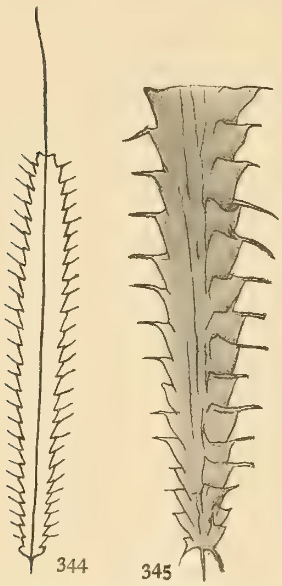
Diplograptus whitfieldi Fearnsides. Section C. No. 6. Belfast. 1902. (separatum)

Description. Synrhabdosome not observed. Rhabdosome of medium size (attaining a length of 35+ mm), beginning with a width of .8 mm, gradually (within 10 mm) increasing to the full width, which is 2 to 3 mm; thence parallel margined or slightly diminishing towards the antisicular extremity, which is truncate. Nemacaulus thin, .1 mm wide; its free end projecting sometimes to a length equal to that of the rhabdosome. Sicula not observed. Sicular extremity furnished with a little conspicuous virgella and two short lateral spines. Thecae numbering 9 to 11, mostly 10 in 10 mm (22–28 in 1 inch), inclined at an angle of about 30°. Three times as long as wide, overlapping one half their length; ventral and apertural margins straight, the latter normal to the axis of the thecae. Aperture pro-

tected by two [*see* "Remarks"] straight, rigid mucros (.8–1 mm long), which are horizontal or slightly ascending in direction.

Position and localities. This species is here found only in the Normanskill shale, at the Normanskill, Glenmont, Stockport and other localities. It is recorded from the rocks of the same age in Canada, but not from the next zone. Gurley has also recognized it in the graptolite fauna of Arkansas, which is also of Normanskill age. In Great Britain it is a Glenkiln form.

Remarks. There is reasonable doubt as to the generic position of this species. Frech has cited G. whitfieldi as the typical form of the spinose subdivision of Diplograptus, into which he would incorporate the genus Glossograptus, holding that the latter is based on fibrous appendages which are not suitable for generic distinction. We have seen, however, that other more important structural differences from Diplograptus s. str. are combined with the spinosity. In G. quadrimucronatus these have been observed in macerated specimens. In the present species, which in its general aspect is still more similar to Diplograptus than quadrimucronatus, the lateral row of spines characteristic of typical Glossograpti has not been observed, but also in G. quadrimucronatus it occurs but in rudimentary condition and in but one mutation. On the other hand there is on the opposite side of the slab bearing the type of G. whitfieldi a specimen that shows well the apertural and lateral ledges characteristic of the Retiolitidae, and a comparison of the enlargement of the type specimen, here given in figure 345, with the drawings of G. quadrimucronatus will readily show the identity of the aspects. Subhorizontal spines are seen at the right corners of the apertures on one side, and at the left corners on the opposite side. It is, hence, proper to infer that the aperture was furnished with two spines in positions like those



344 345

Fig. 344, 345 Glossograptus whitfieldi (Hall). Fig. 344 Copy of original figure. Fig. 345 Portion of type specimen (in Amer. Mus. Nat. Hist.). × 5

of G. quadrimucronatus; and that also the periderm had a like structure, in short that G. whitfieldi belongs to the same subdivision of Glossograptus as G. quadrimucronatus.

The compressed specimens can, as a rule, be readily distinguished from those of G. quadrimucronatus by their more slender rhabdosomes and the slightly ascending direction of the spines. In regard to the "reproductive appendages" of this species, described by Hall, see under Lasiograptus.

Glossograptus ? eucharis (Hall)

Plate 26, figures 18, 19; plate 27, figures 11-13

Retiograptus eucharis Hall. Geol. Sur. Can. Can. Org. Rem. Decade 2. 1865. p.146; pl. 14, fig. 9

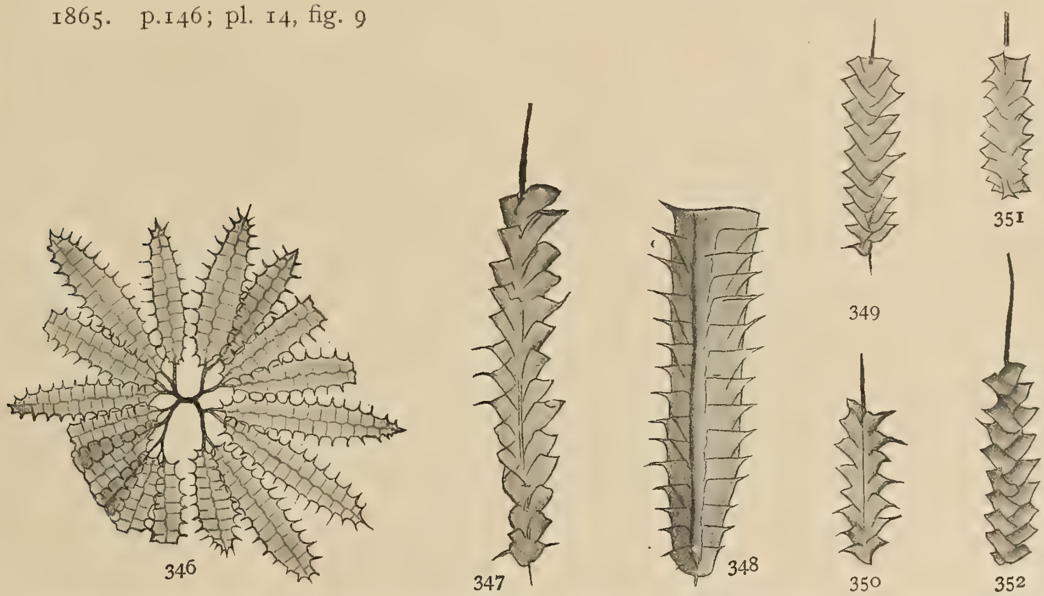


Fig. 346-52 Glossograptus ? eucharis (Hall) Fig. 346 Copy of original figure. Fig. 347 Lateral view of large rhabdosome. Mechanicville. (x 5⅓). Fig. 348 Retiograptus aspect of rhabdosome [*compare* fig. 346]. Dolgeville. Fig. 349-52 Various aspects of rhabdosomes. Fig. 349 External view, shows first theca. Dolgeville. Fig. 350 Specimen from Rural Cemetery, Albany. Fig. 351 Specimen from Diplograptus bed, Elgin, Ia. Fig. 352 Impression of exterior. Mechanicville. Figures 348-52 are x 5

Retiograptus eucharis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.206, 224; pl. 4, fig. 9

Retiograptus eucharis Walcott. Alb. Inst. Trans. v. 10, 1881. (Advance sheet. 1879. p.35)

Retiograptus eucharis Ami. Can. Geol. Sur. An. Rep't. pt 11, 1887-88. 1889. p.23K, 117K

Reteograptus ? eucharis Ami. Can. Rec. Sci. 1893. 5:180, 236

Diplograptus pristiniformis Ruedemann. Am. Jour. Sci. Ser. 1895. 18:453, 455, fig. 2, 3

Diplograptus pristiniformis Wiman. Geol. Inst. Upsala. Bul. 1895. v. 2, pt 2, p.69, 71, fig. 2, 3

Diplograptus ruedemanni Gurley. Jour. Geol. 1896. 4:298, 307

Diplograptus ruedemanni Ruedemann. N. Y. State Geol. 14th An. Rep't. 1897. p.221 ff; pl. 1, fig. 2–10; pl. 2, 3, 5

Diplograptus ruedemanni Tornquist. Zoolog. Centralbl. 1897. 4:5

Diplograptus cf. aculeatus Frech. Roemer & Frech. Lethaea Pal. 1897. 1:632; pl. A, fig. 2

Diplograptus ruedemanni et spinulosus (*nom. nud.*) Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.523 ff

Description. Colony small (average diameter 15 mm, but sometimes attaining the double size) forming a synrhabdosome composed of the central parts and an indefinite number of rhabdosomes (upward of 20 in fairly complete specimens). Rhabdosomes 7 to 10 mm long, of nearly uniform width (1.5–2 mm wide according to the direction of compression). Sicula minute (.8 mm), provided with a needle-shaped virgella. Thecae closely arranged (16–20 in 10 mm, 40–50 in 1 inch) straight, short (1 mm long) and broad (twice as long as wide) and little inclined (angle of inclination of thecae 40°). Aperture straight, normal to axis of theca, furnished with one (or two ?) long, straight or recurving spines. Nemacaulus thin, straight and mostly short, but such twice the length of the rhabdosome have also been observed.

Position and localities. The types of this species came from the Utica shale of Lake St John. Ami records it also from the Utica shale of the Montmorency river, Quebec, and of St Helen's island near Montreal.

The present writer has observed it in considerable number in various outcrops of the Utica shale in the Mohawk and Hudson valleys, the most notable of which are those on the East Canada creek near Dolgeville, Rural cemetery near Albany, west bank of the Hudson river above Waterford and at Mechanicville. It has also been noticed in the shales transitional from the Trenton to the Utica beds at Panton on the east shore of Lake

Champlain and in collections from Holland Patent, N. Y. and the neighborhood of Floyd, N. Y. In all these localities it is associated with typical Utica fossils and it has not been found in either the underlying or overlying formations.[1] It also has been identified in a collection from the Diplograptus bed in Elgin, Ia. (zone of Asaphus gigas-iowensis).

Remarks. This minute form was originally referred by Hall to his genus Retiograptus and described and figured as having the "cell partitions alternating, essentially rectangular to the axis," which is a direction of thecal growth quite different from that of other graptolites. It was the only diprionid form known then to grow in compound colonies (synrhabdosomes).

When the present writer, a few years ago, had an opportunity to see authentic specimens of this species from the original locality, he found them to possess a typical Diplograptus structure and to show in the majority of the rhabdosomes the usual inclined thecae of a Diplograptus. The facts in the case are hence the following: the draftsman has taken the peculiar state of preservation of some rhabdosomes, in which the apertural margins of both series of thecae are shown on both sides of the axis, as the normal state of preservation and extended this upon the whole colony. Professor Hall drew up his description of this very small graptolite from the drawing, as I have since learned from Professor Whitfield, thereby mistook these apertural margins for the cell partitions and thus came to assign the form as a peculiar type to Retiograptus. For this reason the species has failed to be recognized by subsequent authors, though Hall's figures had been frequently copied and the form has a wide distribution. The present writer wrongly identified his material with Diplograptus pristiniformis and Dr Gurley upon receiving material from me and perceiving this error described it as a new species, while Frech compared it to D. aculeatus Lapworth.

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[1] This statement may need qualification in regard to the occurrence at Sandy Hill, N. Y., where this species has been obtained at a recent visit in an association indicating a somewhat greater age of the beds [*see* p.31]. To the list of Sandy Hill forms Diplograptus foliaceus is to be added.

The figures here given serve to illustrate the various states of preservation of the rhabdosome, figure 348 representing that which led to the first misconception.

It is remarkable how much more frequently this form is found in whole colonies than all the other diplograptids, among which synrhabdosomes are most astonishingly rare. The writer has seen synrhabdosomes of G. eucharis from the type locality, from Dolgeville, where they were quite common in one place and from other outcrops in the Mohawk valley (Holland Patent, Canajoharie), Waterford and Millers brook and Kent brook near Floyd, N. Y. (the latter in Amer. Mus. Nat. Hist.). This frequent preservation of the whole colony is evidently due to the smallness of the same and the shortness of many nemacauli.

G. eucharis is readily distinguished from all other associated forms by its small size, the extremely close arrangement and broad, short form of the thecae. The development of the spines seems to have been subject to considerable variation; they were found to be of remarkable length and curved in some localities and horizons, as at the Rural cemetery and again but inconspicuous and straight in others, as at the dam in Mechanicville.

CLIMACOGRAPTUS Hall. 1865

This genus was proposed by Hall with C. bicornis as type. The original description is:

> Simple stipes with subparallel margins, having a range of cellules on each side; axis filiform; cellules short and square; apertures apparently excavated in the margin of the stipe, and transversely oval or subquadrate; cell denticles or appendages, if present, usually on the upper side of the aperture.

The principal character of Climacograptus is to be seen in the peculiar geniculation of the thecae which in their proximal part are attached parallel to the axis, then turn outward and finally again become parallel to the axis thereby placing the aperture into a more or less deep, transverse excavation between two successive thecae. As the earlier and more primitive species (as C. pungens and C. putillus) apparently are those to be regarded in which the middle part is still obliquely instead of rectangularly

directed and occupies a large proportion of the theca; while the distal free part is also, though less, oblique, the ventral wall of the theca exhibiting but a slight sigmoid curvature. These forms still approach the Diplograptus stage or rather — since both Diplograptus and Climacograptus appear side by side with their typical characters in the zone with Phyllogr. anna and Diplogr. dentatus, — the common ancestor of the two genera. The preceding Axonolipa all possess plain, straight, tubular thecae, which are inclined to the axis and not at all suggestive of the thecal form of Climacograptus, with the sole exception of the Leptograptidae. The thecae of the latter, as Lapworth, Elles and Wood have pointed out, possess a slightly sigmoid curvature and have their apertures situated partly within depressions (excavations). These curvatures and the apertural excavations are in them developed very slightly indeed, but they may properly be considered as indicating the phylogenetic path to the thecal development of Climacograptus, as well as of the Dicranograptidae. In forms of Climacograptus, with zigzagged sutures, the sigmoid form of the thecae is more distinct than in those with straight sutures, but also in the latter the steplike form of the thecae is distinctly but a variation of the sigmoid curvature, probably induced by the straightening of the rhabdosome.

As will be observed in the descriptions of the species, there exist within the confines of Climacograptus considerable differences in regard to the relative lengths of the parallel and oblique parts of the thecae, the depths of the apertural excavations and the directions of the free ventral walls and apertures. On account of these various stages of development of the thecal form it is sometimes difficult to assign a form properly to its genus by the latter criterion alone and especially the distinction between Diplograptus and Climacograptus becomes uncertain. This difficulty is still increased by the fact that a typical Diplograptus may be thus compressed and split with the imbedding shale, that it assumes the aspect of a Climacograptus and vice versa. This explains why some forms as Diplogr. perexcavatus were not definitely placed in one of the two genera until specimens in full or partial relief were obtained.

A difference of some diagnostic importance between the two genera may rest in the presence or absence of a longitudinal septum. Hall, the author of the genus Climacograptus, held that in this genus as in Diplograptus the thecae were simple openings in the outer test of a single internal coenosarcal canal. Nicholson afterwards claimed that the rhabdosome of Climacograptus consisted of two monoprionidian branches placed back to back, and separated by a double median septum, consisting of the flattened dorsal walls of the branches. Lapworth has later verified Nicholson's theory in regard to C. scalaris and several of its varieties and C. wilsoni and suggested that within the limits of Climacograptus, as at present conceived, are included some forms in which the median septum is continuous from side to side, and others in which the thecae of both series open into one and the same central coenosarcal canal. Törnquist has shown in his "Observations on the structure of some Diprionidae" [1893] by means of thin sections that the species of Diplograptus investigated, had either no median septum at all (D. bellulus) or a very incomplete one (D. palmeus and Cephalograptus cometa where it is "reduced to a narrow fold of the obverse periderm"); while in Climacograptus there are first formed a series of alternating thecae from the common canal (Törnquist's "biserial chamber") as in Diplograptus, after which the biserial chamber divides into two "uniserial chambers" which are separated by a longitudinal septum. The number of pairs of alternating thecae is different in different species; C. scalaris was thus found to have two of them, while in C. rectangularis the septal line in the reverse aspect does not begin until beyond the eighth pair of thecae; and in C. undulatus the zigzagged septal groove begins at the sicular end.

Almost simultaneously with Törnquist Wiman made his investigations on etched material of Diplograptidae [1893 and 1895]. He showed the origin of such a longitudinal septum in Climacograptus [*see* text fig. 353] by means of a monopodial branching of a theca, the third theca (in C. kuckersiana) sending out two thecae, first one (t4, d in figure) toward the side of the second theca, and then one (t5) towards the side of the first

theca. It is true, Wiman states in the same publication [1895, p.37] that he also observed in Diplogr. uplandicus a rather distally beginning septum; but it is not apparent whether this is not an incomplete septum such as Törnquist observed in Cephalogr. cometa resulting from a narrow fold of the obverse periderm; and when we examine the drawings and species available of both genera, Diplograptus and Climacograptus, it becomes apparent that in Climacograptus a sutural groove is always present and always begins near the sicular end, allowing but a short "biserial chamber," while in Diplograptus the lateral faces are nearly always smooth on both the obverse and reverse sides, or at least on the latter, indicating the absence of a complete longitudinal septum or the presence of only a fold of the periderm on the obverse side without a division of the rhabdosome into two uniserial chambers.

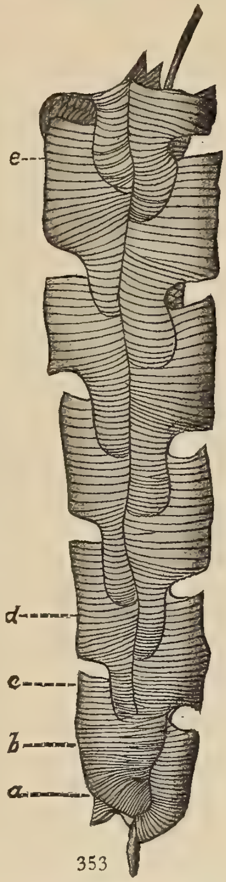


Fig. 353 Climacograptus kuckersianus Holm. Reverse view. x 32. Copy from Wiman

In forms like C. putillus where the double geniculation of the thecae and the apertural excavations are still so little developed that a reference to Diplograptus is possible, the presence of a distinct septal suture [*see* fig. 370] beginning near the sicular end, is an argument for a closer relationship to Climacograptus and I have therefore placed it with that genus.

If we wish to arrive at an understanding of the phylogenetic bearing of the relative development of the biserial and uniserial chambers, we shall have to resort, as in the case of the form of the theca of Climacograptus, to the Leptograptidae, in which, according to the important observation of the British monographers, two crossing canals are present instead of the one of the other Axonolipa. That means that here two pairs of alternating thecae are developed, before the rhabdosome divides into two uniserial chambers. Taking for granted the derivation of Climacograptus from

some Leptograptuslike form, by means of an alteration of the sigmoid curvature of the theca into a double geniculation and the coalescence of the free uniserial arms by their dorsal sides, the smaller or greater number of alternating pairs of thecae and the corresponding earlier or later development of the longitudinal septum would appear to be well able to give some clues as to the stage of development of a particular species, the smaller number of alternating thecae indicating a lower stage. It then also becomes impossible to derive Climacograptus from Diplograptus, the latter genus according to this criterion and in this regard being more advanced than Climacograptus by the extension of the biserial chamber on the whole or the greater part of the rhabdosome.

Synrhabdosomes of Climacograptus have not yet been found, but it is hardly to be doubted that as in Diplograptus and Lasiograptus, also in this genus the rhabdosomes were combined into colonies of a higher order. The expansions of the nemacaulus observed so frequently in certain species of Climacograptus can not be considered as part of the central organs, for the nemacaulus is seen in some cases to proceed beyond them. Their structure and function have been discussed on page 88.

The first attempt at subdividing the genus, of which I am aware, has been made by Frech, who, seeing in the two lateral spines of the sicular end[1] functionally important organs, makes them the principal criterion of distinction, thereby separating C. bicornis and C. antennarius from the rest of the congeners. The latter form is a true Cryptograptus, and to be removed from this association, thus leaving C. bicornis alone in the first group. And its spines can be hardly given more than varietal rank as diagnostic characters; for many of the other congeners (as C. parvus, C. modestus, C. caudatus, C. antiquus) possess small lateral spines; in one species (C. typicalis) the typical specimens seem to lack them while a mutation is furnished with them; and also

[1] They are called "Sicularstacheln" by him, which term is not appropriate in the case of Climacograptus bicornis, as the two lateral spines are borne by the first two thecae and not by the sicula, from which the third spine, the virgella, proceeds.

in members of other genera (Diplogr. foliaceus, Glossogr. quadrimucronatus) varieties and mutations possess homologous lateral spines, while they are absent in the typical forms.

It is probable that if true phylogenetic relations are to be made the basis of subdivision, more than two groups of species are to be recognized and that whole aggregations of characters and especially the form of the thecae have to be used as criteria of distinction. Elles and Wood have in the last instalment of the *Monograph of British Graptolites* which has recently appeared, divided the genus Climacograptus by the characters of the thecae, notably the direction of the free edge of the ventral wall and of the apertural margin, and thus obtained five groups. These, in the whole, coincide with the grouping here arrived at.

One natural group within the species of Climacograptus here described is formed by C. pungens, C. typicalis and C. putillus. These have in common the form of the neastic thecae, which are very long and narrow, little overlapping and possess horizontal or slightly everted apertural margins. In C. pungens and C. putillus this thecal form persists throughout; in C. typicalis it is only characteristic of the earlier rhabdosome. A further common character, which is very suggestive of a close genetic relationship, is the presence of mesial mucros or spines situated at the point of the second geniculation of the thecae, just above the apertural excavations [*see* fig. 375]. C. pungens is the earliest of these species; it belongs to the third Deepkill zone and is probably of Chazy age. C. putillus appears in a mutation in the Trenton and typically in the Utica shale; it is so closely related to C. pungens [*see* Mem. 7, pl. 16, fig. 19, 20] that its direct derivation from that form can not be doubted. C. typicalis is in the sicular portion of its rhabdosome hardly distinguishable from C. putillus, thereby indicating its origin; but then changes rather abruptly in the character of the thecae and in size attained passes way beyond its relatives. C. innotatus Nicholson [1869, p.238] from the Birkhill shales is apparently a younger British representative of the same race, it possesses the same spines as C. typi-

calis [*see* fig. 377] as Nicholson correctly observed and judging from his drawing and description also thecae similar to the earlier (neastic) thecae of C. typicalis. We would also derive C. scalaris from this group.

Another natural group among our species of Climacograptus is formed by C. parvus, C. modestus and C. scharenbergi. It is rather well characterized in the compressed condition, by the nearly uniform width of the rhabdosome, square-shaped free distal parts of the thecae, the deep, narrow, horizontal apertural excavations and the prevailing presence of lateral spines at the sicular end, and in the plastic form by the more or less zigzagged shape of the sutural groove and the corresponding considerable divergence of the directions taken by the different parts of the theca. C. scharenbergi is the oldest and most typical form of this group. C. bicornis with its extreme development of the lateral spines and C. caudatus with an equally extreme development of the virgella stand apart of this group by their gradually widening rhabdosomes, the wide, but shallow apertural excavations and the oblique direction of the free distal parts of the thecae. Both of these may be connected with C. antiquus which is older as well as similar and, possessing both long lateral spines and a long virgella, would seem well fitted to have given rise to these two species.

The range of the genus corresponds in our region approximately to that found in Europe. There is one species, C. pungens, found in the third Deepkill zone (with Dipl. dentatus); six are known from the Normanskill shale, two of which persist (mutationally differentiated) into the Utica and Lorraine beds; one is found in the beds intervening between the Normanskill and typical Utica beds (zone of Dipl. amplexicaulis); another is restricted to the Utica shale and one is here described from the Clinton beds of Maine.

Climacograptus typicalis Hall

Plate 28, figures 6, 7

Climacograptus typicalis Hall. Can. Org. Rem. Dec. 2. 1865. p. 27, 28, 57; pl. A, fig. 1–9

Climacograptus typicalis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1868. pl. 2, fig. 1–9

Climacograptus typicalis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. Rev. ed. 1868. pl. 2, fig. 1–9

Climacograptus typicalis Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets, 1879. p.34)

Climacograptus typicalis Ulrich. Am. Geol. 1888. 1:183

Climacograptus typicalis Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Climacograptus typicalis Winchell & Schuchert. Geol. Minn. 1895. v. 3, pt 1, p.82, fig. 4

Climacograptus typicalis Gurley. Jour. Geol. 1896. 4:298

Climacograptus typicalis Roemer & Frech. Lethaea Pal. 1897. 1:612

Climacograptus typicalis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.523 ff

Climacograptus typicalis Nickles. Cin. Soc. Nat. Hist. Jour. 1902. 20:68

Description. Synrhabdosome not observed. Rhabdosome long (66 mm+), narrow, with extremely narrow whip-shaped sicular end (.3–.4 mm) which in the space of about 16 mm attains the mature width (2–2.4 mm). The latter is maintained to the growing end. Lateral sides convex, smooth, broad. Sutural grooves so faint that they are observed only in exceptional cases. Sicula short (1.2 mm), its aperture possessing two short mucros. Thecae closely arranged (11–15 in 10 mm), overlapping one third in mature part, one fourth and less at sicular end; twice bent; in the proximal half parallel to axis of rhabdosome, then abruptly turning outward at nearly right angle and finally again becoming parallel to axis. Aperture horizontal to slightly everted (especially in neastic part) apertural excavation short (one fourth of ventral margin) and deep (one fourth of width of rhabdosome). Nemacaulus very thin and short and hence rarely observed.

Position and localities. Hall cites this species from the "Hudson river"; Walcott from the Utica and "Hudson" shales; Winchell and Schu-

chert from the Galena limestone of Minnesota and Wisconsin (?) and the Cincinnati group at Cincinnati; Ulrich [1888] assigns it to his beds XI a and b, and Gurley to the Utica and lower Cincinnati and Nickles lists it, in his Geology of Cincinnati, among the forms ranging through the Utica, but does not cite it from the Lorraine group. In this State it is also restricted to the Utica shale and is there one of the most common and characteristic graptolites. It is as frequent in the belt of Utica slate paralleling the Hudson as in that girdling the south and west of the Adirondacks. It seems to be absent in the beds transitional from the Trenton to the Utica, but has been observed in the late Utica horizons where Lorraine forms make their appearance [Ruedemann, Bul. 42, p.526].

The Canadian geologists do not mention this species in their fossil lists, but it is quite possible that it is hidden under the designation C. bicornis; for it extends through the Champlain basin where I collected it at the south end of Grand isle.

In the West C. typicalis has a greater range than has been observed here for it may occur in the Galena limestone, and I have before me typical specimens from the lower third of the Eden shale in Covington, Ky. [Ulrich coll.]

A "(?) C. aff. typicalis Hall ou confertus Lapworth" is cited by Flamand [1905] among the graptolites from the central Sahara. Since it is associated with Siluric forms, identity with our species is out of question.

Remarks. It is peculiar that this species though frequently illustrated has never yet been described. At first Hall probably comprised it under his Graptolithus scalaris [Pal. N. Y., v. 1, pl. 73, fig. 4c]; in the *Canadian Organic Remains* it is fully illustrated in all its characters, but in the text only mentioned in the table showing the geologic distribution of the species.

This type is easily recognized by its slender, whiplike sicular end and the very small overlap of the early thecae, giving them the appearance of being freely suspended or of rectangular hooks. Also the aspect of the

thecae of the mature part of the rhabdosome is very characteristic, their distal free parts standing out as series of squares from the broad median part of the lateral face. This squarish aspect of the thecae is, besides their straight apertures and straight outer margins especially due to their equally straight outer walls opposite the apertures of the preceding thecae. This geniculated part of the thecal wall is so much thicker than the others that it clearly stands out above the latter and in some specimens it is even produced into a mucro [*see* text fig. 354]. In all other congeners this part of the thecal wall is very distinctly concave or depressed.

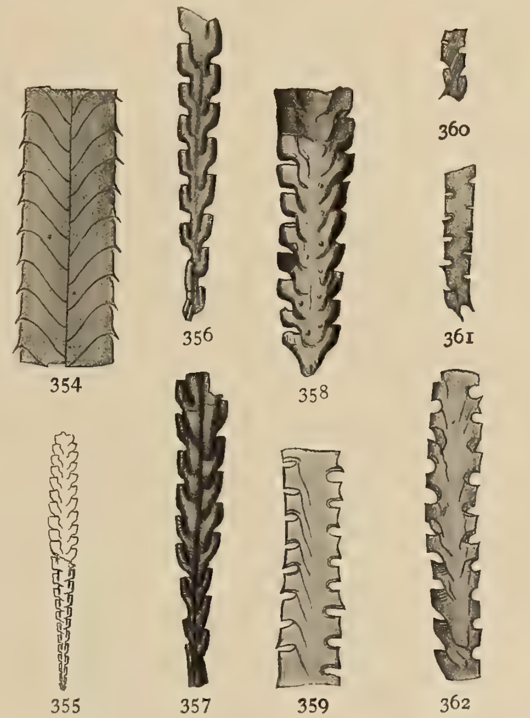


Fig. 354-62 Climacograptus typicalis Hall. Fig. 354 Copy of one of Hall's original figures, representing a longitudinal section. Fig. 355 Gurley's ms drawing. x 2. Fig. 356 Sicular end of a typical specimen from Holland Patent, N. Y. x 7. Fig. 357 Sicular end of a slightly different mutation in shale dredged from river at Troy, N. Y. Fig. 358 Mature portion of rhabdosome of typical specimen from Holland Patent, N. Y. Fig 359-61 Mature portion and sicular extremities of specimens from lower third of Eden shale at Covington, Ky. (Ulrich coll.). Fig. 362 Portion of variety from Lees Gulf, Lewis co., N. Y. x 5

From C. bicornis, with which it may be found associated, it differs, aside from the absence of the lateral spines, in the narrower sicular extremity, the more rapid and less uniform widening of the rhabdosome and the wider apertural excavations. The only species of Climacograptus in the graptolite shales of New York that possesses a similarly slender sicular extremity is C. caudatus. This goes still beyond C. typicalis in the slenderness of its rhabdosome and attains its maximal width much slower. C. parvus has squarish thecae like C. typicalis, but it can for this reason not yet be considered as a dwarfed mutation of C. typicalis, as Frech has done [1897, p.610]; for it precedes the latter and is separated from its horizon by the zone of Diplograptus amplexicaulis in which it is absent, and it has a greatly different rhabdosomal outline.

The rhabdosomes of C. putillus are so much like the narrow sicular ends of those of C. typicalis that it would seem necessary to unite the two, were it not for the fact that in certain layers of the Utica shales (as at Mosher's creek in the Mohawk valley) innumerable specimens of the former species are found, all of which attain a uniform small size, apparently that of the mature form, and that the thecae of C. putillus are still a little longer.

In Lees gulf near Turin, Lewis co., I have found shales lying probably little below the base of the Lorraine, filled with a mutation of C. typicalis [*see* pl. 28, fig. 7] that is principally marked by its failure to attain the full width of the type form and the markedly slower widening of the rhabdosome. At a distance of 15 mm (approximately the maximal length of the rhabdosome of this mutation) from the sicula the width is but 1.2 mm against 2.2 mm in the type. Also the thecae do not increase materially in size and there are 15 counted in the space of 10 mm throughout the length of the rhabdosome. For the latter reason these can not be merely young rhabdosomes of C. typicalis; but they rather appear as rhabdosomes that have failed to attain mature characters while outgrowing the young in size.

Hall has figured the transverse section of the rhabdosome as concavo-convex. Specimens embedded in Galena limestone from St Paul, Minn., have enabled us to verify this observation. It has been found that the concave or flat side is the obverse and the convex the reverse side.

This asymmetric section also explains another peculiarity of this species, viz, the different aspects of the thecae on the obverse and reverse sides; a difference best seen when a specimen preserved in relief is partly broken out, as in the original of figure 355. In the latter the lower thecae appear as narrow vertical tubes, suggesting handles, while in the impression of the other side they are broad, overlapping and separated by short, shallow apertural excavations. This difference in the two sides is very characteristic of C. typicalis and also easily observed in the flattened specimens from the Utica shale. Its cause is seen in cross-sections to lie in the

fact that the thecae are not growing exactly in the axial plane of the common canal, but are all slightly curving out of this plane toward the obverse side, which thereby becomes flat or concave in section, while the reverse side from which the thecae grow away, becomes depressed towards the margins and convex in section. Hall's original section (6) shows this position of the thecae very well.

This is not the only peculiar character of this species, distinguishing it from nearly all of its congeners in this country. The narrow spikelike sicular part with its widely separated thecae is another feature not observed in other species and the absence or very late separation into two series of thecae and the correlative late formation of a dividing septum constitutes a third distinguishing character.

The mature parts of C. latus Elles and Wood, a form of the last Champlainic (Ordovicic) zone in Europe, resemble those of this species very much in the broad lateral face and relatively small squarish free parts of the thecae. We undoubtedly have to see in it a vicarious form of the late Champlainic derivatives of C. typicalis described in this memoir.

Climacograptus typicalis Hall mut. spinifer nov.

Plate 28, figures 8, 9

Inspection of the original of the first figure of C. bicornis illustrating Hall's description of that species shows at once that this specimen, which comes from Ballston, Saratoga co., differs greatly from the typical C. bicornis, as it occurs in the Normanskill shale. We reproduce here a more exact drawing [pl. 28, fig. 8] of the same to bring out its peculiar characters. The State Museum contains slabs from Bakers falls in the same county, which are identical in their lithologic characters with the slab bearing Hall's original and like that slab contain no other fossils but this graptolite, that proves to be a peculiar mutation (or variation ?) of C. typicalis. The character of the earliest thecae [*see* text fig. 363] is especially convincing of this. The rhabdosome remains, however, distinctly narrower (in Hall's original its width is only 1.2 mm, in the widest specimens from Bakers falls 1.8 mm) and the thecae are closer arranged, the

majority of the specimens having 14 thecae in 10 mm even in the mature parts. But the most conspicuous difference from the typical C. typicalis is the presence of the two straight, thin spines reminding of the sicular spines of C. bicornis. There are no such lateral spines observable on any of the multitude of specimens of C. typicalis covering the slabs of Utica shale in the Mohawk valley or on those from the Cincinnati beds, while they are clearly a constant character in the Saratoga county specimens.

But the best preserved of the Cincinnati specimens of C. typicalis show a thin needlelike virgella and a mucro at the opposite side of the sicular aperture [*see* text fig. 361]. The two spines of our mutation are now quite clearly, from their angle of divergence and their place of insertion further prolongations of these sicular spines, hence not homologous at all to the two lateral spines of C. bicornis, which grow from the first two thecae.

Fig. 363 Climacograptus typicalis mut. spinifer nov. Sicular end of rhabdosome. × 5

The question could arise whether since Hall's first figure of C. bicornis represents a specimen belonging to this mutation, the latter should not be considered the type of C. bicornis, but the reading of Hall's original description will convince any one that he took the Normanskill form for the typical one of C. bicornis and his later erection of the species C. typicalis corroborates this view. No confusion can, therefore, be possibly caused by referring this first figure of C. bicornis to the mutation of C. typicalis where it properly belongs. For the latter we propose the name C. typicalis var. spinifer. The exact horizon at which it occurs has not yet been established.

Climacograptus ulrichi sp. nov.

Plate 28, figures 10, 11

Description. Synrhabdosomes not observed. Rhabdosomes small (12–18 mm). Sicular end as in C. typicalis, narrow and acutely pointed, furnished with short stout virgella and an opposite, parallel, sicular

mucro [*see* fig. 364]; rhabdosome attaining its full width (1.8 mm) within 3 mm, its margins parallel thereafter. A free prolongation of the nemacaulus mostly present, attaining half the length of the rhabdosome. First one or two pairs of thecae narrow and appressed to nemacaulus as in C. typicalis; later thecae bent twice; the middle part directed obliquely outward and the proximal and distal parts subparallel to axis of rhabdosome. Aperture normal to distal part of theca; interthecal excavation long (one third the length of theca) but shallow (one fourth width of rhabdosome); subtriangular in outline. Thecae numbering 12 in 10 mm (30 in 1 inch).

Formation and locality. The specimens were obtained by Dr Ulrich in the Maquoketa shale at Spencer, 20 miles south of St Louis, Mo.

Remarks. This, the latest Champlainic American Climacograptus known to the writer, presents some interesting features. Its sicular end is that of a C. typicalis, while in its general habit and size it reminds of Diplogr. peosta. The restriction of the narrow, appressed form of the thecae to two pairs and the rapid, sometimes even abrupt widening of the rhabdosome beyond these suggest a tachygenetic process and that C. ulrichi may be a last remainder of the stock of C. typicalis. The later thecae are greatly different from those of C. typicalis and would by the slightly oblique margins of their distal parts indicate a form with less typically climacograptid thecae than the genotype. The specimens are so badly flattened that neither the character of the lateral faces nor the presence or absence of a septal groove could be determined.


365


364

Fig. 364, 365 Climacograptus ulrichi sp. nov. Fig. 364 Type specimen. Fig. 365 Sicular end of another specimen showing the sicula. x 5

Climacograptus mississippiensis sp. nov.

Plate 28, figures 12, 13

Description. Synrhabdosomes not observed. Rhabdosomes small, maximum length observed 15 mm, length of majority of specimens 7 to

10 mm; width at sicular extremity, .6 mm, increasing quite rapidly to maximum width of 2 mm. Sicular extremity furnished with rodlike virgella (1.8 mm long), but without lateral spines. Lateral faces flat or slightly concave, nearly smooth. Septal groove beginning at the sixth pair of thecae on the obverse side and apparently absent on the opposite side. Sicula long and slender (1.8 mm). Thecae numbering 12 in 10 mm in the sicular part of the rhabdosome and 10 in the same space in the mature part (25–30 to the inch), of the form of those of C. typicalis. Apertures and apertural excavations also as in the latter species. Nemacaulus thin, rarely protruding and then but a short distance.

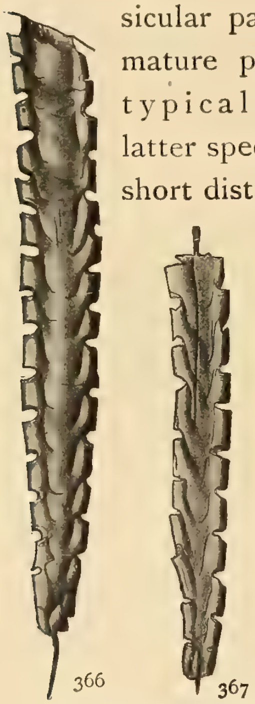


Fig. 366, 367 Climacograptus mississippiensis sp. nov. Fig. 366 Type specimen, preserved in demirelief. Fig. 367 Smaller rhabdosome. x 6½

Locality and formation. Collected by Dr E. O. Ulrich in the Sylvan shale of the Arbuckle mountains in Indian Territory.

Remarks. This species suggests at once its close relationship to C. typicalis by the long free parts of the thecae and the short, narrow apertural excavations, but it differs distinctly from that species in the greater width of the earliest part of the rhabdosome, the more gradual and more uniform widening of the rhabdosome, its section and the less close arrangement of the thecae (10–12 against 11–15 in 10 mm); differences which warrant its separation as a distinct species.

This form though not growing as wide as the European C. latus has the character of the thecae and the rapid increase in width in the earlier stages in common with the latter and may well be considered as a close relative or vicarious form of the same. C. latus is found in the zone of Dicellograptus anceps and is hence one of the last graptolites of the Lower Siluric.

Climacograptus putillus (Hall)

Plate 28, figures 14, 15

Graptolithus putillus Hall. Geol. Sur. Can. Org. Rem. Dec. 2. 1865. p.27, 44; pl. A, fig. 10, 11, 12, 12a

Diplograptus putillus Hall. State Cab. Nat. Hist. 20th An. Rep't. 1868. p.195, 211; pl. 2, fig. 10, 11, 12, 12a

Diplograptus putillus Nicholson. Geol. Soc. Quar. Jour. 1868. 24:527; pl. 19, fig. 17, 18

Diplograptus putillus Walcott. Alb. Inst. Trans. v. 10, 1883. (Advance sheets. 1879. p.35)

Diplograptus putillus Tullberg. Sver. Geol. Unders. ser. C. no. 50. 1882. p. 43

Diplograptus putillus Lapworth. Roy. Soc. Can. Proc. & Trans. 1886. 4:170, 178 ff

Diplograptus putillus Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Diplograptus putillus Ami. Can. Rec. Sci. (1892–93) 1893. 5:244

Diplograptus putillus Gurley. Jour. Geol. 1896. 4:298

Graptolithus (Diplograptus) putillus Winchell & Schuchert. Geol. Minn. 1895. v. 3, pt 1, p.82, fig. 3

Diplograptus putillus Nickles. Jour. Cin. Soc. Nat. Hist. 1902. 20:68

Diplograptus teretiusculus Hisinger sp. var. putillus Frech. Roemer & Frech, Lethaea Pal. 1896. 1:628

Diplograptus putillus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.498 ff

Diplograptus putillus Winchell & Ulrich. Geol. Minn. 1897 v. 3 pt 2, p.CXI

Description. Rhabdosome very small (9 mm, mostly less) and slender (1–1.3 mm wide), elliptic in section, widening gradually, possessing a gently wavy median furrow on each lateral face. Sicula small (1.3 mm) and very slender, provided with a short apertural spine; its slender virgella protruding from the rhabdosome. Thecae tubular, little inclined to the axis of the rhabdosome in the proximal half and subparallel to it in the distal free half; closely arranged (12–14 in the space of 10 mm or 32 in 1 inch); apertures straight, at right angles to longer axes of thecae. Nemacaulus thin.

Position and localities. Hall cites the form from the " Hudson River formation in Iowa ".; his type in the American Museum of Natural History is labeled " Maquoketa creek, Iowa." To Gurley it was only known from the lower Maquoketa shale of that state and Winchell and Schuchert record it from the " Hudson River group," near Granger and near Spring Valley, Minn.; and Graf, Ia.; Winchell and Ulrich, in the synoptic list of fossils, given in the second part of the above cited work, place it in the Utica group of Minnesota and cite it also from the same formation in the Cincinnati region. Its occurrence in the latter region is shown by two small slabs in the Ulrich collection, which are covered with this fossil and come from the lower third of the Eden shale. Nickles, in his geology of Cincinnati cites it among the forms which range through the Utica. Material from the Diplograptus bed at Graf in Iowa, supplied by Professor Sardeson contains this form but less abundant than Diplograptus peosta and in collections from Granger I have failed to find it. Specimens of a light drab shale from Arkansas [center sec. 13, 35, 17W] are covered with it [U. S. Geol. Sur. Coll.].

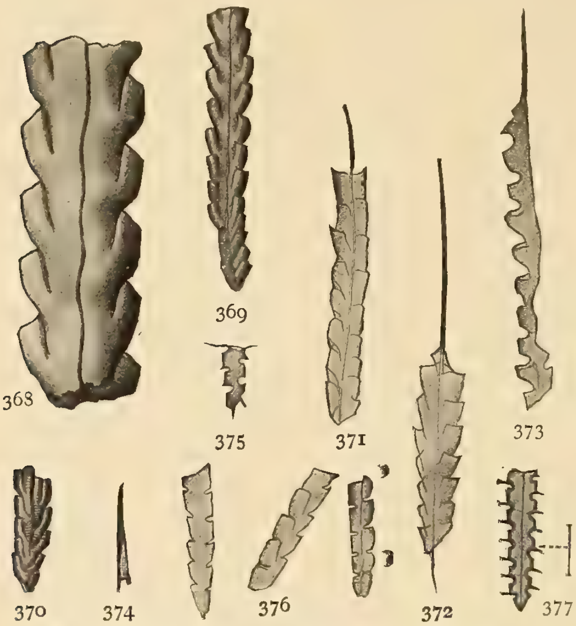


Fig. 368-77 Climacograptus putillus (Hall). Fig. 368 Copy of one of Hall's original figures (x 12). Fig. 369 Hall's type. Fig. 370 Specimen on same slab with type, showing sicular end. Fig. 371-73 Specimens from Rural cemetery; the last one showing profile view of one row of thecae. Fig. 374 Sicula. (x 7). Fig. 375 Sicular end of specimen from lower third of Eden shale in Kentucky. Fig. 376 Group of specimens from Flat creek, near Mohawk, N. Y. Fig. 377 C. innotatus Nicholson, copied for comparison from Nicholson. All enlarged x 5, except where differently stated

The present writer has found it to be a common fossil in the outcrops of the Utica shale in the Hudson valley (as at Waterford, Rural cemetery near Albany, where it occurs not infrequently and in fine preservation; Penitentiary and Beaver park at Albany, Black creek near Voorheesville) and in the Mohawk valley, where, however, it has never been seen in the

lower Utica beds at Dolgeville but completely covers certain layers in the higher beds at Flat creek near Mohawk village. It is also found north of Utica, near Amsterdam, etc.

In the Lake Champlain region I have collected it along the Panton shore in Vermont in the beds transitional from the Trenton limestone to the Utica shale, where it is associated with Glossogr. quadrimucronatus and G. (?) eucharis.

An occurrence in the lower Lorraine (Frankfort) beds at Waterford [*see* Bul. 42, p.514] indicates that this species may also enter the Lorraine stage, but I have not observed it in collections from the higher Lorraine beds.

Ami has recognized C. putillus in the Utica terrane of the Ottawa outlier in Canada. Nicholson has identified a form from the Coniston flags of Skelgill Beck, near Ambleside, Scotland, with Hall's species. The identity of the two seems to be open to doubt, since the Scottish form is coarser in its dimensions, widens very gradually (judging from Nicholson's drawing) and has but 25 thecae in 1 inch. Tullberg has named a zone in Scania after this graptolite.

Remarks. This species was described by Hall in the introduction to his Graptolites of the Quebec group [p.44] as presenting a modification of the general arrangement of the thecae in the ordinary forms of Diplograptus in so far " that the apex of one theca barely reaches the base of the next succeeding." This conception is due to the approach of the second half of the theca to a direction subparallel to the axis of the rhabdosome. Hall's excellent figures [*see* copy in text fig. 368] and the type specimen [refigured fig. 369] fail to show the proximal half of the theca, which as shown by another specimen on the same slab with the type [*see* fig. 370], is overlapped by the preceding theca. There is hence an overlap, though it is notably smaller than in other American Diplograpti. In the change of the growth direction of the thecae and the slight overlap this form shows a decided approach to Climacograptus, which in compressed specimens is brought out still more distinctly by the appearance of the apertures as trans-

verse notches [*see* fig. 376, of specimens from Mosher creek]. Also the wavy median furrow of the lateral face is a feature regularly observed in Climacograptus but in Diplograptus only seen in the small group, of which D. teretiusculus is the typical representative. The small fragment, associated with the type and reproduced in figure 370 shows distinctly that this furrow does not begin until about the fourth pair of thecae, a feature also visible, though less distinctly in the type itself. If this furrow indicates that the double series of alternatingly budding thecae has here separated into two coalescing series of successively budding thecae we have another feature, before observed in Climacograptus.

It is true, the apertural excavations in C. putillus are not as narrow and slitlike as in a typical Climacograptus, but it may here be remarked that the early thecae of C. typicalis, are exactly formed like those of C. putillus and that the apertural excavations in that species do not become narrow until the overlap of the thecae has greatly increased.

Frech [1896, p.628] has pointed out the great similarity of this form to Diplograptus teretiusculus and even suggested that it should be regarded as only a variety of that important Scandinavian and English form. Though indeed this European species seems to differ only by attaining a greater length and somewhat greater width of the rhabdosome and has approximately the same number of thecae in 10 mm, it appears at much earlier horizons (zone with Didymograptus geminus and Glossograptus) and is the earliest Diplograptus in Scandinavia, following directly upon subzone *r* (with Didymograptus bifidus), and approximately of Chazy age. If our form, which for this reason I should keep separate, turns out to be a direct descendant of that Atlantic and Baltic form, it is a very late and interesting survival in the American basin of that old European stock.

The mutation from the Normanskill shale at Lansingburg, described here, demonstrates that this species existed, though in a rare and small mutation, before Utica time in the Appalachian basin and spread out into the American epicontinental basin in that age. There is even good ground for

suspecting that this group existed already in the Appalachian (Levis) basin before Trenton time, for the form from the third Deepkill zone described in Memoir 7 as C. pungens is so much alike in general form and size, in shape and closeness of arrangement of thecae to C. putillus and Dipl. teretiusculus [*see* especially ibid. pl. 16, fig. 19] that it can be fairly assumed that better material will show its close relationship to these species, and its horizon also corresponds to that containing D. teretiusculus in Europe. It can therefore be considered as a vicarious form of that European species and may eventually be shown to be the progenitor of C. putillus.

In regard to the latter relationship a small feature is of great interest which I had occasion to observe in the beautifully preserved specimens of the Ulrich collection. This is the presence of minute mucros [*see* text fig. 369] at the point of abrupt widening of the thecae just above the apertural notches. These mucros correspond to similar, longer spines of C. pungens [*see* Mem. 7, pl. 16, fig. 14].

In the compressed state it is very difficult to distinguish the rhabdosome of C. putillus from the young rhabdosome of its associate C. typicalis, which beginning very narrow and widening slowly, presents a strikingly like aspect. The slightly greater length of the thecae of C. typicalis will serve as a distinguishing character where both are commingled [*compare* fig. 361 and fig. 375].

This species is also related to C. innotatus Nicholson, a considerably younger form (Llandovery, Middle Birkhill) with which it has the dimensions and character of thecae in common. It is especially interesting to note that the later innotatus possesses long mesial spines on the lower outer corners of the free walls, where C. putillus and C. typicalis develop mucros. It may for this reason be considered as a paracmic form of the C. typicalis-putillus race.

Climacograptus putillus (Hall) mut. **eximius** nov.

Plate 28, figure 16

Cf. Diplograptus putillus Lapworth. Roy. Soc. Can. Proc. & Trans. 1886. 4:170, 178ff

Diplograptus aff. putillus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.541

The typical putillus has in the shales of New York State been found only in the Utica and Lorraine horizons. In the shale near the power house at Lansingburg, the writer has found a mutation of C. putillus occurring in great numbers associated with Normanskill forms; and also the Normanskill shale near Glenmont, Albany co., has afforded a few specimens. This mutation is distinctly narrower (its width only .7–1 mm), of somewhat greater length (10 mm, average 8 mm) and has especially a closer arrangement of the thecae (16–18 thecae in 10 mm or 40–45 in 1 inch). The form of the thecae is exactly as in C. putillus [*see* text fig. 380, 381]. While most specimens possess only a short virgella at the sicular extremity, a few are distinctly furnished with short lateral spines [text fig. 378].

378 379 380 381 382 383 384

Fig. 378–84 Climacograptus putillus mut. eximius nov. Fig. 378–82 Different aspects of typical specimens from Lansingburg. (x 5). Fig. 383 Specimen from Glenmont, N. Y. (x 5). Fig. 384 Sicular end of rhabdosome from Lansingburg, enlarged x 6

Lapworth has doubtfully referred to C. putillus specimens observed by him in collections of the Coenograptus-gracilis zone (Normanskill shale) on the south side of the St Lawrence (Tartigo river, Griffin Cove) and from Cape Rouge and designated that species as a long range form, which passes through that zone and into the next British one above. There is little doubt that the Canadian specimens of the Dicellograptus zone to which Lapworth refers belong also to this mutation.

Climacograptus scalaris (Hisinger) var. (mut. ?) **annulatus** nov.

Plate 28, figure 32

Synonymy of Climacograptus scalaris:

Non Graptolithus scalaris Linné. Syst. Nat. Ed. XII. 1768. p.175 (no fig.)

Orthoceratites tenuis Wahlenberg. Petrificata Tell. Suec. Nova acta Reg. Soc. Scient. Upsal. 1821. 8:93

Prionotus scalaris Hisinger. Leth. Suec. 1837. p.113; pl. 35, fig. 4a, b

Graptolithus palmeus (ex parte) Barrande. Grapt. de Bohême. 1851. pl. 3, fig. 5, 6

Climacograptus teretiusculus (ex parte) Nicholson. Ann. Mag. Nat. Hist. 1870. 6:376, fig. 2a

Climacograptus scalaris Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 2, fig. 47

Climacograptus scalaris Marr. Geol. Soc. Quar. Jour. 1880. 36:604

Climacograptus scalaris Lapworth. Belfast Field Club, Rep't & Proc. Ser. 2. 1877. v. 4, apx. p.137

Climacograptus scalaris Tullberg. Bih. till K. Vet.-Akad. Handl. 1882. 6:9; pl. 1, fig. 12–14

Climacograptus scalaris Törnquist. Lunds Univ. Arsskrift. 1891. 26:23 (separatum)

Climacograptus scalaris Törnquist. Kongl. Fysiogr. Sällsk. Lund Handl. Ny Följd. 1893. 4:2 (separatum) pl. 1, fig. 1–22

Climacograptus scalaris Törnquist. *Ibid.* 1897. 8:5 (separatum) pl. 1, fig. 1–8

Climacograptus scalaris Lapworth. Geol. Mag. Ser. 3. 1889. v. 6, table II, facing p. 68

Climacograptus scalaris Perner. Etudes sur les Grapt. de Bohême. 3 pt, sec. a. 1897. p.7; pl. 10, fig. 1–6

Climacograptus scalaris Roemer & Frech. Lethaea Pal. 1897. 1:613, fig. 178

Cf. Climacograptus sp. Katzer. Sitz.-ber. der k. böhm. Gesellsch. d. Wiss. 1896. p.12 (separatum) pl. 2, fig. 3–11

Non Graptolites scalaris Vanuxem. Geol. N. Y. 3d Dist. 1842. p.57

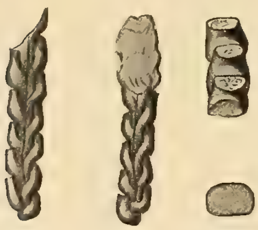
Non Graptolites scalaris Hall. Pal. N. Y. 1847. 1:271; pl. 73, fig. 4 g

Non Graptolithus scalaris Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets. 1879. p.35)

Non Climacograptus scalaris Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Non Climacograptus scalaris Ami. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 2, p.117K

Description. Synrhabdosome not observed. Rhabdosome small (10–14 mm long and 1.1 mm wide), with parallel sides and broadly elliptical section. Sicular and antisicular extremities rounded. Lateral faces possessing slightly undulating median sutures (complete septum). Virgella and free nemacaulus not observed. Sicula small, slender, a little more than 1 mm long. Thecae numbering 10 to 12 in the space of 10 mm; twice bent, first parallel to axis of rhabdosome (first third), then obliquely upward at angle of 30° (second third) and finally again into parallelism to axis of rhabdosome in distal third. Apertural margin oblique, or slightly everted; apertural excavations triangular notches (one fourth of length and one fourth of width of rhabdosome).



385 386 387

Fig. 385–87 Climacograptus scalaris var. annulatus nov. Fig. 385, 386 Two views of type specimen. (x 5). Fig. 387. Frontal view of thecae and cross-section of rhabdosome. (x 7)

Position and localities. Numerous specimens were found in a boulder of ferruginous sandstone, probably of Clinton age, collected by Mr Olof O. Nylander, of Caribou, Me. at Aroostook, Me. No associated fossils were observed.[1]

This species, which hitherto has not been found in North America, has the distinction of being one of the longest known and most widely distributed graptolites. In Europe it is especially well known from Scandinavia, where it occurs in Scania in the last zone of the Champlainic (Ordovicic) which according to Lapworth is already a basal zone of the Siluric, is especially common in the higher horizons of the lower Siluric (Rastrites shale) and is the index form of the C. scalaris shale. Törnquist records it from the first zone of the Scanian Rastrites beds (zone of Diplogr. acuminatus) and the third and fourth zones, in the latter of which it is the most common

[1] Mr Nylander writes that the boulder apparently comes from the sandstone belt west of the Aroostook limestone and the Chapman sandstone.

graptolite. According to Frech it occurs in the second and third zones (Monogr. gregarius and M. convolutus) of the Siluric of Ostrogothia (Motala), Westrogothia and Bornholm; in Germany it is found near Görlitz in Silesia and in Thuringia; from the Bohemian stage Ee_1 it has been recorded by Marr, and Perner assigns it to the so called Colonies Haidinger, d'Archiac and Karlik with Monogr. becki, M. spiralis, etc.; in Great Britain Lapworth has found it in the upper Hartfell shales (third zone, of Dicellogr. anceps, etc.) of the Moffat series; the var. normalis in the Scottish Birkhill shales, and the Llandovey beds of Wales and the west of England, and abundantly in Coalpit bay in Ireland. It is also known from France (Anjou), Belgium (Gembloux, etc.), Russian Poland (Kielce), China, where v. Richthofen collected it on the south slope of the Lunschan, Prov. Kiangsu. Probably also the diprionic graptolites figured by Katzer from the quartzites of the Maecuru (basin of Amazonas) are as Frech mentions to be identified with this species.[1]

C. scalaris was well established in the Baltic basin, Bohemian-Mediterranean basin and the different parts of the Atlantic basin, as demonstrated by the occurrences in Europe and Maine and eventually that in Brazil. It also occupied the western Pacific ocean, but strangely enough it has not been found anywhere in the Clinton deposits of the eastern Mississippian sea.

Remarks. The history of this species has been briefly given by Lapworth [1877; *see also* Tullberg, 1882, and Törnquist, 1891, 1897] and Törnquist [1893] has worked out most elaborately the internal structure of the rhabdosome by means of thin sections. From Lapworth's remarks we learn that the form figured by Linné as Graptolithus scalaris was a

[1] They are associated with a Monograptus and agree well in form and dimensions of rhabdosome, form and arrangement of thecae with the specimens here identified with C. scalaris. Katzer's figures 5, 6, 7 show the variations in the septal suture, also noticed in this description and figures 3, 4, 8 exhibit the opposite position of the thecae that is only possible where two separate series of thecae are developed. The peculiar, recurving apertural parts of figure 8 may indicate a form like C. undulatus Kurck with globular apertural protuberances.

Monograptus from the higher Siluric beds in which Climacograptus is unknown.[1] Hisinger, hence, for practical reasons should be made the author of C. scalaris.

Törnquist has among other facts shown that in the initial part of the rhabdosome, a "biserial chamber" is found, which after having produced two pairs of regularly alternating thecae, is divided by the median septum into two uniserial canals originating in the common chamber. This difference between the initial and other parts of the rhabdosome is also distinctly shown in the specimens from Maine, by the character of the median suture upon the lateral faces [*see* text fig. 385], the first two pairs of thecae being clearly interlocked or alternating and the straight suture beginning above them.

The specimens from Maine are preserved only as quartz fillings of the somatic cavities and all periderm is lost. In these fillings the obliquely directed parts of the thecal tubes are much inflated and the initial and distal parts depressed. The result of this is that the rhabdosome appears strongly annulated in its more distal parts, where the thecae have ceased to be alternating and as a rule are placed directly opposite each other. It can hardly be assumed that this feature is entirely due to a much varying thickness of the periderm and that the proximal and distal parts of the thecal walls were much thicker than the middle part, for there is nothing seen in the sections of C. scalaris published by Törnquist to indicate any such differences in thickness of the periderm.[2] Nor is there any trace of inflation shown in the exterior views of periderms given by Törnquist.[3] His careful

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[1] Tullberg [1885, p.5] and Törnquist [1897, p.6] consider the straight body on the slab as a Climacograptus, probably different from Prionotus scalaris Hisinger.

[2] It must, however, be admitted that the thin sections of Monograptus furnished by Perner show that sometimes considerable differences exist in the thickness of the thecal walls.

[3] These inflations have nothing to do with the globular protuberances of C. undulatus Kurck, which are "free prolongations of the lower lamina of each thecal partition" that extend downward over the aperture.

longitudinal sections [for instance 1893, pl. 1, fig. 7, 8] demonstrate, however, that the distal ventral margins of the thecae were slightly directed inward and the thecal tubes slightly wider in the middle than at either end. The same is seen in the figure here given, but the main inflation in our material takes place in lateral direction, as the frontal view [text fig. 387] of a rhabdosome shows. This lateral inflation gives a bottle-shaped appearance to the frontal view of the distal parts of the thecae. It is probable that this is an extreme development of a feature of C. scalaris and of varietal character, the importance of which can not be determined until the periderm itself is observed.[1]

Aside from these intermittent inflations, the transverse sections of the rhabdosome are considerably less rounded and more rectangular than those figured by Törnquist [*see* text fig. 387]. It is hence for the present safer to separate this form at least varietally from Hisinger's type. In general form, curvature and closeness of arrangement of thecae, the specimens from Maine agree well with the Swedish types. Their rhabdosomes do not reach the length of the latter, a difference quite probably due to the fragmentary character of the material.[2]

The septal suture is in the Maine specimens subject to extreme variation; it is rigidly straight in some (or the most) and in others as extremely zigzagged as in C. scharenbergi. Between the two extremes are found various transitions and in some cases the same suture is partly straight and partly zigzagged. Those with strongly zigzagged sutures are relatively wider and shorter, but since they lie parallel to the others, their present form can not be due to secondary shortening within the rock.

Hall has referred a number of specimens from the Utica shale of the West Canada creek and the Normanskill shale near Albany, showing only the scalariform frontal aspect, to Graptolithus scalaris Linné.

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[1] The maximum lateral inflation occurs exactly where the new theca buds and both features are obviously connected causally.

[2] In its dimensions this variety is most suggestive of the variety miserabilis since described by Elles and Wood.

Of these those figured on plate 73, figures 4a and 4b represent the frontal aspect of a C. bicornis; 4c and 4d that of a C. typicalis; 4e and 4f a folded condition of some undeterminable form, probably a Didymograptus sagittarius and 4g, a C. parvus.

Climacograptus parvus Hall

Plate 28, figures 19–23

Climacograptus bicornis Hall (ex parte). Pal. N. Y. 1847. v. 1, pl. 73, fig. 2e, k, o–s

Climacograptus parvus Hall. Can. Org. Rem. Dec. 2. 1865. p.57 (*nom. nud.*)

Climacograptus parvus Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets. 1879. p.34)

Climacograptus parvus Walcott. Geol. Soc. Am. Bul. 1890. 1:339

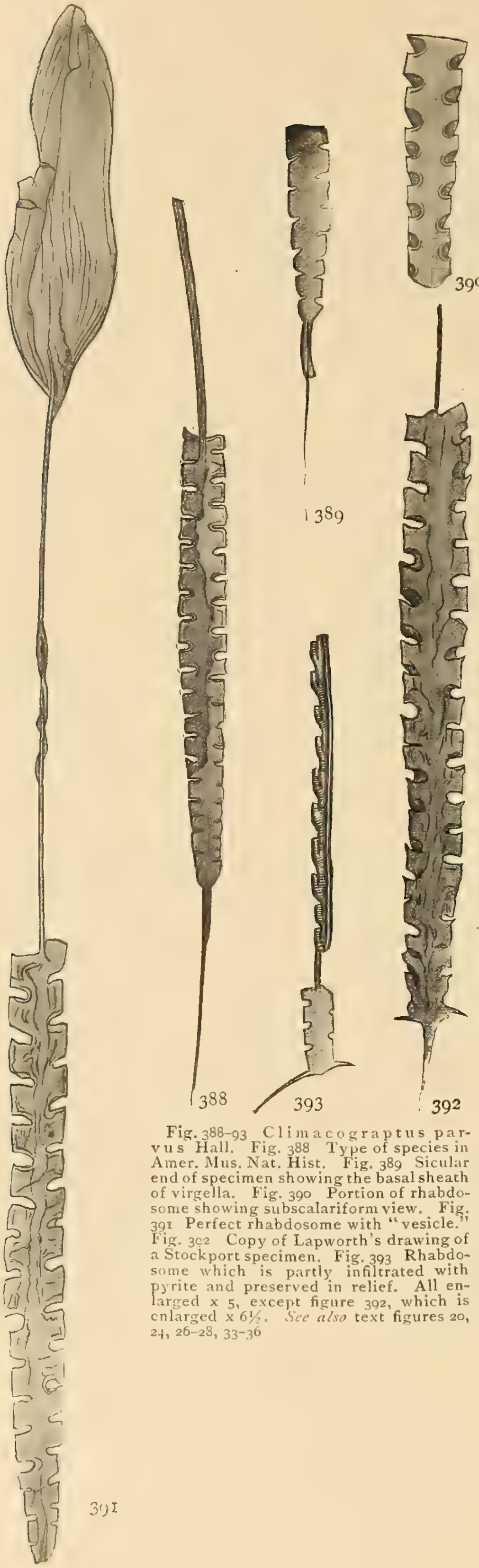
Climacograptus phyllophorus Gurley. Jour. Geol. 1896. 4:77; pl. 4, fig. 4–6; p. 297

Climacograptus parvus Roemer & Frech. Lethaea Pal. 1897. 1:610

Climacograptus parvus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.523 ff

Climacograptus phyllophorus Weller. Geol. Sur. N. J. Pal. 1902. 3:53

Climacograptus parvus Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33



391 388 389 393 390 392

Fig. 388–93 Climacograptus parvus Hall. Fig. 388 Type of species in Amer. Mus. Nat. Hist. Fig. 389 Sicular end of specimen showing the basal sheath of virgella. Fig. 390 Portion of rhabdosome showing subscalariform view. Fig. 391 Perfect rhabdosome with "vesicle." Fig. 392 Copy of Lapworth's drawing of a Stockport specimen. Fig. 393 Rhabdosome which is partly infiltrated with pyrite and preserved in relief. All enlarged x 5, except figure 392, which is enlarged x 6½. *See also* text figures 20, 24, 26–28, 33–36

Description. Synrhabdosome not observed. Rhabdosome small, in the

majority of specimens 20 mm long (maximal length observed is 32 mm) rapidly attaining (in length of five to six thecae) its full width which is 1.5 to 2 mm. Sicular extremity possessing a long rodlike virgella (6.5 mm long) with a broad basal membrane (or prolongation of the opposite lappet of the sicula ?) and two short straight horizontal lateral spines. Antisicular end truncate, not narrowing.

Nemacaulus thin, but rigid and long; frequently possessing in mature specimens a vesicle, which varies in form from narrow lanceolate to broadly elliptic, attains a maximal length of 10 mm and a width of 4 mm and is not situated terminally. Sicula slender, about 1.3 mm long. Thecae numbering 12 to 15 in 10 mm; in the usual, completely flattened state showing straight, or slightly concave outer margins of the distal free parts, which appear as squarish projections between the deep elliptical horizontal excavations, that occupy about one third of the ventral margin and in mature specimens one third the width of the rhabdosome. In specimens showing full relief [*see* fig. 393] the proximal part of the theca is seen to be narrow and parallel to the axis, the ventral wall of the distal free part is slightly inclined inward and the apertural margin slightly introverted. The overlap is not much more than one third the length of the theca. The septum extends the greater length of the rhabdosome.

Position and localities. Hall listed C. parvus as one of the forms of the "Hudson River formation." Gurley records it as occurring at Stockport, Columbia co., N. Y. and calls it one of the most characteristic forms of the Lower Dicellograptus zone (Normanskill shale). The writer has observed it in collections from numerous outcrops of the same zone in the slate belt of New York, especially in those from the Normanskill and Glenmont near Albany; Mt Moreno near Hudson; Castleton; Schodack Landing; Mt Olympus and Poestenkill at Troy; Granville in Washington county, etc. This species has not been recognized by the Canadian geologists and is not cited by them, but undoubtedly extends with the Dicellograptus fauna through Vermont into the St Lawrence region. Outside of the Levis channel the form has not yet been found or recorded.

Remarks. As in the case of C. typicalis, Hall included this species at first in C. bicornis, the figures 2e, 2o, 2p, 2r, 2s of volume 1, *Palaeontology of New York*, representing specimens of the same; and like C. typicalis, this species when recognized, was not described, but only cited in the table showing the geographical distribution of the graptolites, and not even figured. There is in the Hall collection in the American Museum of Natural History a specimen with Hall's printed label "Clim. parvus," of which fig. 388 is an enlargement. This specimen, which is from the Normanskill shale at Kenwood, may properly be used to base the species upon. Gurley has in 1896, on the ground that Hall's term remained a *nomen nudum*, renamed and described the species as C. phyllophorus Since, however, authentic types of Hall's material are available (and have been used by Gurley according to his own admission, *ibid.* p.77) and the form is well known under its old name among paleontologists, it is neither necessary nor desirable to drop that name.

C. parvus bears similarity to C. antiquus and C. scharenbergi; it is by the character of its thecae and apertural margins shown to be a closer relative of the former, with which it has also the long virgella and basal membrane in common. It differs from it by the closer arrangement of the thecae and its smaller dimensions in general.

The most peculiar character of this species is to be seen in the vesicle, which has been fully described and figured in the introductory chapter on the dilatations of the nemacaulus [p.90 ff].

Climacograptus scharenbergi Lapworth

Plate 28, figure 31

Climacograptus scharenbergi Lapworth. Cat. West. Scott. Foss. 1876. p.6, pl. 2, fig. 35

Climacograptus scharenbergi Lapworth. Belfast Club, Rep't & Proc. Ser. 2, v. 1, pt 4. 1877. Apx. p.138; pl. 6, fig. 36

Climacograptus scharenbergi Linnarsson. Sver. Geol. Und. afh. och upps. Ser. C, no. 31. 1879. p.18

Climacograptus scharenbergi Lapworth. Geol. Mag. Ser. 3. 1889. v. 6, table II

Climacograptus scharenbergi Tullberg. Sver. Geol. Und. afh. och upps. Ser. C, no. 50. 1882. p. 21 f

Climacograptus scharenbergi Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:180

Climacograptus scharenbergi Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:276 ff

Climacograptus scharenbergi Törnquist. Sartr. Kongl. Fys. Sällsk. Lund Handl. 1893. 4:8; pl. 1, fig. 28

Climacograptus scharenbergi Gurley. Jour. Geol. 1896. 4:298

Climacograptus scharenbergi Roemer & Frech. Lethaea Pal. 1897. 1:609, 611, 612, fig. 176

Climacograptus scharenbergi Elles. Geol. Soc. Quar. Jour. 1898. 54:519

Climacograptus scharenbergi Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.541 ff; pl. 1, fig. 1

Climacograptus scharenbergi Ruedemann. N. Y. State Mus. Bul. 49. 1901. p.11; pl. 3, fig. 1

Climacograptus scharenbergi Clark. Geol. Mag. Ser. 4. 1902. 9:498

Climacograptus scharenbergi Fearnsides. Section C. Belfast. 1902. p.1 (separatum)

Climacograptus scharenbergi Elles & Wood. Monogr. Brit. Grapt. pt 5. 1906. p.206; p.207, fig. 139; pl.27, fig. 14

Description. Synrhabdosome not observed. Rhabdosome small and uniformly narrow, attaining a length of 32 mm and a width of 2 mm (in the compressed state, 1.3 mm; in majority of specimens); rounded at sicular extremity (.05 wide) and rapidly widening, attaining its full width in the length of about 10 thecae; ventral margins subparallel; antisicular end not contracted, and abruptly terminating; sicula only partially visible, virgella present, but short; lateral spines little developed. Median sutural groove of lateral face deflected into a zigzag line, from the outer points of whose angulations short horizontal grooves run out at right angles. Thecae numbering 11 to 13 in 10 mm; little overlapping (one fourth of length); their proximal half parallel to nemacaulus; and then bending abruptly outward approximately at right angles and again into subparallelism to the nemacaulus with a slight inward inclination; the apertural margin normal to free

distal part of theca (horizontal to slightly introverted) ; the apertural excavation wide and deep in specimens preserved in relief, occupying one fourth to one third the length of the theca and one third to two fifths the width of the rhabdosome ; in compressed specimens narrower and deeper.

The nemacaulus relatively thick (.2 mm).

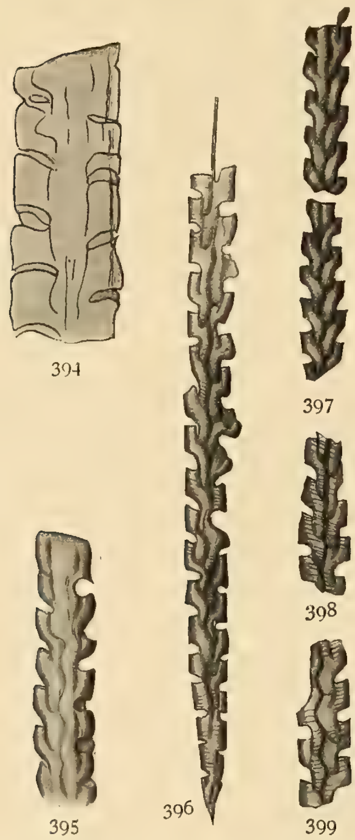


Fig. 394–99 Climacograptus scharenbergi Lapworth. Fig. 394, 395 Copies of Lapworth's original ms drawings of British specimens (x 9 and x 6½). Fig. 396 Well preserved specimen from Glenmont (not preserved in as high relief as shaded). Fig. 397 Specimen from Rysedorph hill conglomerate. Fig. 398, 399 Two sides of fragment from Mt Moreno, preserved in demirelief. x 5

Position and localities. In Great Britain this species is widely distributed (Scotland, the Lake District, Shropshire, Wales and Ireland) and has a very long range, for it is already reported from the Ellergill beds in the Upper Skiddaw Slates (Elles) which are thought to correspond to the Llanvirn of Wales (Upper Arenig) in age and is there associated with forms occurring in our third Deepkill zone and below. Frech even claims [1897, p.612] that Roemer has collected it near Christiania in Phyllograptus shale with Phyllograptus typus and P. angustifolius. From the Llanvirn it ranges through the Llandeilo into the lower Caradoc [Lapworth, 1880, 1889] where it is one of the common forms of the C. wilsoni zone of the lower Hartfell shales and it is also well known in Scandinavia, where in Scania it is reported from the zone of Diplograptus putillus by Tullberg.

In America it has been first observed by Lapworth in collections from various outcrops of the Trenton shales in the province of Quebec (Griffin Cove and Island of Orleans, etc.) and Gurley has also listed it from the "Upper Dicellograptus zone" at Magog, Canada. The present writer found it in a specimen preserved in relief [*see* text. fig. 397 and Bul. 42, 49, 1901] associated with Ampyx (Lonchodomas) hastatus and

Pterygometopus callicephalus in a black limestone pebble of the Rysedorph conglomerate, which is intercalated in Normanskill shale. This specimen must be hence of greater than Normanskill age and probably belongs to a subzone not yet recognized (approximately of Black river age). The museum collection from the Normanskill shale of Glenmont near Albany, contains a slab that is covered with a great number of rhabdosomes of this species, in association with Clim. bicornis and Dipl. foliaceus. Other specimens have been found at Mt Moreno near Hudson.

Remarks. The most characteristic feature of this species is seen in the deflections of the sutural groove and the short horizontal grooves proceeding from the outer angles of the former. This structure is well shown in text figure 399, taken from a specimen which though somewhat compressed, has not lost all relief. The latter and that from Rysedorph hill [text fig. 397] which is preserved in full relief, show that the short horizontal grooves mark the budding places of the new thecae. They also indicate that the proximal part of the theca is not strictly parallel to the nemacaulus but corresponding to the zigzag sutural groove inclines first inward, then turns at an angle of about 140° obliquely outward and in the last, distal part assumes a direction parallel to the axis of the rhabdosome.

From C. parvus this species differs, aside from the markedly deflected groove, in the more gradual widening of the rhabdosome. In a strongly compressed state the two are similar, but the remarkably deep notches or apertural excavations, which separate the narrow, rectangular, free ends of the thecae, instead of the square ones of parvus, will always permit a separation. The connection between the full relief specimens of C. scharenbergi from the Rysedorph hill conglomerate and the very dissimilar, much compressed films from the Normanskill shale at Glenmont is formed by a few specimens in demirelief condition found at Mt Moreno [*see* fig. 399].

Climacograptus modestus sp. nov.

Plate 28, figure 30

Description. Synrhabdosome not observed. Rhabdosome narrow (.7–1.4, in the majority of specimens 1 mm wide), but attaining considerable length (21 mm). Sicular extremity broadly rounded, rhabdosome attaining full width within the space of a few thecae and maintaining this to antisicular extremity which is abruptly cut across without preceding narrowing. Sicular extremity furnished with short virgella and two straight horizontal lateral spines. Sutural groove zigzagged with short, horizontal lateral branches. Sicula 1.5 mm long, slender. Thecae very closely arranged, numbering 14 to 18 (mostly 16) in the space of 10 mm, overlapping one third of length, bent twice, two fifths of length adhering to nemacaulus and directed slightly inward, one fifth directed abruptly, almost at right angles outward and last two fifths subparallel to axis of rhabdosome or slightly inclined inward. The distal free part of theca squarish in compressed specimens; the apertural excavations in the latter are narrow horizontal notches, whose depth is one fourth to one third of the width of the rhabdosome. The septum extends the whole length of the rhabdosome and is apparently complete. Nemacaulus thin and short.

Fig. 400–3 Climacograptus modestus sp. nov. Different aspects of typical specimens. Sicular end of specimen 400 not preserved in as strong relief as shaded. Figure 401 enlarged x 5, the others x 5½

Formation and localities. This species is very common in one of the layers of the Normanskill shale at Mt Moreno, near Hudson, N. Y. and has also been observed in a few specimens in the same horizon at the north end of Lansingburg.

Remarks. C. modestus is similar to C. parvus in some features

and to C. scharenbergi in others. With the former it has the uniform width of the rhabdosome and the form of the thecae — especially the square shape of the distal part — in common, but differs in the smaller width and greater length of the rhabdosome, the closer arrangement of the thecae, the presence of two lateral spines, the small development of the virgella and the thin, short projecting nemacaulus. Probably if observed at all, it has hitherto not been differentiated from C. parvus; but its differential and specific characters are constant in the great number of specimens occurring in certain layers. With C. scharenbergi it has the zigzagged sutural groove and the short horizontal side grooves in common, but differs in the considerably closer arrangement of the thecae. According to the form of the thecae it is most nearly related to the latter species with which it has especially the zigzagged median groove, the slight introversion of the free distal part and the abrupt outward bend of the middle part of the thecae in common. Altogether the great number of small square free distal thecae is a feature by which this species will be easily recognized.

Climacograptus bicornis Hall

Plate 28, figures 24–26

Graptolithus bicornis Hall. Pal. N. Y. 1847. 1:268; pl. 73, fig. 2a–s

Diplograptus bicornis Geinitz. Die Graptolithen. 1852. p.24

Diplograptus bicornis M'Coy. Ann. & Mag. Nat. Hist. 1862. 9:139

Climacograptus bicornis Hall. Can. Org. Rem. Dec. 2. 1865. p.112; pl. A, fig. 1a–c

Climacograptus bicornis Nicholson. Ann. & Mag. Nat. Hist. 1870. 6:380

Climacograptus bicornis Nicholson. Monogr. Brit. Grapt. 1872. p.61, fig. 29a–d

Diplograptus (Climacograptus) bicornis M'Coy. Prodr. Pal. Victoria. Dec. 1. 1874. p.12; pl. 1, fig. 8

Climacograptus bicornis Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 2, fig. 51

Climacograptus bicornis Lapworth. Geol. Soc. Quar. Jour. 1878. 34:250

Climacograptus bicornis Lapworth. Belfast Field Club. Rep't & Proc. Ser. 2, v. 1, pt 4, apx. 1877. p.139; pl. 6, fig. 38a

Climacograptus bicornis Whitfield. U. S. Geol. Sur. West 100th Merid. Wheeler's Rep't Pal. 1877. 4:19

Climacograptus bicornis Linnarsson. Sver. Geol. Und. Ser. C, no. 31. 1879. p.18

Climacograptus bicornis Lapworth. Ann. Mag. Nat. Hist. 1880. 6:22

Climacograptus bicornis Tullberg. Sver. Geol. Und. Ser. C, no. 41. 1880.

Climacograptus bicornis Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p.20

Climacograptus bicornis Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets. 1879. p.34)

Climacograptus bicornis Whitfield. Am. Jour. Sci. Ser. 3. 1883. 26:380

Graptolithus bicornis Ford. Am. Jour. Sci. Ser. 3. 1884. 28:206

Climacograptus bicornis Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:178f

Climacograptus bicornis Miller. Am. Geol. 1889. p.178, fig. 153

Climacograptus bicornis Ami. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 2, p.117K

Climacograptus bicornis Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:410

Climacograptus bicornis ? Ami. Can. Rec. Sci. 1892–93. 5:237, 239

Climacograptus bicornis Gurley. Jour. Geol. 1896. 4:297

Climacograptus bicornis T. S. Hall. Roy. Soc. Victoria Proc. 1897. 9:184

Climacograptus bicornis Roemer & Frech. Lethaea Pal. 1897. 1:610, 611, fig. 174

Climacograptus bicornis T. S. Hall. Geol. Mag. n. s. Dec. 4. 1899. 6:445

Climacograptus bicornis Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.496 ff

Climacograptus bicornis Clark. Geol. Mag. Ser. 4. 1902. 9:498

Climacograptus bicornis T. S. Hall. Geol. Sur. Victoria Rec. 1902. v. 1, pt 1, p.34

Climacograptus bicornis Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33

Climacograptus bicornis T. S. Hall. Roy. Soc. Victoria Proc. 1905. v. 18, pt 1, p.21

Climacograptus bicornis Ami. Geol. Sur. Can. Sum. Rep't, 1904. (1905) p.12

Climacograptus bicornis T. S. Hall. Geol. Sur. Victoria Rec. 1906. v. 1, pt 4, p. 275; pl. 34, fig. 8

Climacograptus bicornis Elles & Wood. Monogr. Brit. Grapt. pt 5. 1906. p.193; 194, fig. 126; pl. 26, fig. 8a–f

var. peltifer Lapw. 1876 (p.6; pl. 2, fig. 53); 1877, p.139; pl. 6, fig. 38b

var. tridentatus Lapw. 1876 (p.6; pl. 2, fig. 52); 1877, p.139; pl. 6, fig. 38c

var. tuberculatus Nich. 1869, p.229; pl. 11, fig. 18; Lapw. 1876, p.6

var. longispina T. S. Hall. 1902. Geol. Sur. N. S. Wales Rec. v. 7, pt 2, p.5, pl. 12, fig. 8, 9

Description. Synrhabdosome not observed. Rhabdosome linear in the middle and antisicular portions; attaining great length (10 cm and more); gradually widening from the sicular extremity to a width of 2.6+ mm, attained in about 30 mm and maintained close to the antisicular extremity. The former extremity is always armed with two diverging lateral spines, which grow from the first two thecae, and the virgella which greatly varies in length. The sicula is 1 mm long, its greater portion embedded. The thecae number 12 in the sicular region and 7 in the mature part and overlap about one third their length; their proximal walls are curved, the free distal wall straight and parallel to the axis of the rhabdosome. The apertural margins are horizontal, the apertural excavations wide (one third length of theca) and attaining in depth one fourth the width of the rhabdosome in mature part, and one third in the earlier part. Nemacaulus not observed.



404 405

Fig. 404, 405 Climacograptus bicornis Hall. Fig. 404 Portion of rhabdosome of typical specimen. Fig. 405 Rhabdosome presenting semiscalariform view (middle portion omitted). x 5. *See also* text figures 12–17 and plate A

Formations and localities. Hall, in the original description, states: "This species is among the most common in the slates near Albany, and at Ballston, Saratoga co. It is more rarely seen in the slate in Columbia county, and its occurrence in the Mohawk valley doubtful. It occurs likewise at Cincinnati and other western localities and appears to be the most common species in that part of the country." Walcott, the next author in this country who mentions it, cites it as occurring in the Utica shale (including Normanskill shale) and in the Hudson River (Lorraine) shale. We now know that it is one of the most common forms of the Normanskill shale throughout the New York slate belt, and extends with this formation into the provinces of Quebec and New Brunswick and probably equally far southward into the Appalachian trough though it is not yet recorded south of the State of New York and collections from New Jersey and Alabama have failed to show it. The species persists through the next zone (according to Lapworth in neighborhood of Quebec and according to Gurley at Magog, Canada) and into the Utica shale of the Mohawk valley, whence it has been first recorded by Whitfield. According to the writer's observations it is there represented only by a smaller mutation and of rare occurrence (Dolgeville). In the Utica shale of the Hudson river region this mutation has been only once observed by the writer. It apparently occurred farther south in the Appalachian trough, for a specimen of the same mutation has been noticed in a small collection from Strasburg, Va.

This species, or any mutation of it, has not been traced in-this State into the Lorraine beds. From Hall's statement that it is the most common species at Cincinnati and other western localities, one might conclude that it must be a common Lorraine or Richmond form, but I have failed to find it in the Ulrich collection of graptolites from the Ohio basin, nor is it mentioned by Winchell and Ulrich in the fossil lists of the Champlainic deposits of the Upper Mississippi province [Geol. Min. v. 3, pt 2] or cited by Gurley in his synoptic list of graptolites [Jour. Geol. 1896] from the Cincinnati, Maquoketa and Lorraine shales. It is also absent in a collection of Maquoketa graptolites sent to me by Professor Sardeson. There is hence fair

evidence that this species does not range beyond the Utica formation. In Canada it has been identified with some doubt by Ami in collections from the Utica shale of Lacolle, Quebec, and from the north shore of Lake Huron and the Manitoulin islands.

The last mentioned citation is the only record of the possible presence of C. bicornis in the Mississippian sea in Posttrenton time. But it was well established there in early Trenton (Normanskill) time, as evinced by its frequent occurrence in the graptolite beds of Arkansas [Gurley, 1890]. At that time it probably occupied the entire Pacific basin, for it has been recorded by T. S. Hall from the same horizon and many localities in Victoria, Australia. It is equally well known from the corresponding beds of the Atlantic basin in Great Britain where Nicholson and Lapworth have found it in many places. Lapworth [1878, p.250; 1880, p.283, 358] cites it as one of the Glenkiln or Llandeilo-Bala and Bala-Caradoc forms, marking it as passing through the entire series of Hartfell zones. Its British range would hence correspond to ours with the exception that it seems to exist there to the end of the Champlainic. It is likewise known from Scandinavia (Tullberg).

Remarks. This species, which has been made the genotype of Climacograptus by Hall, is not only the most stately and most common of our representives of the genus, but also the most conspicuous by reason of the remarkable appendages of its sicular extremity. These show such a wide range of modifications that several of them have been recognized as varieties (peltifer, tridentatus and longispinus). On account of their bearing on the morphology of the graptolite spines in general we have discussed them separately in the introductory chapter on spines [*see* p.80], stating there that all these varieties occur in the Normanskill shale together with transitional forms, indicating the climacteric condition of the species at the time.

Climacograptus caudatus Lapworth

Plate 28, figure 17, 18

Climacograptus caudatus Lapworth. Cat. West. Scott. Foss. 1876. p.6, pl. 2, fig. 48

Climacograptus caudatus Lapworth. Belfast Field Club. Rep't & Proc. v. 1, pt 4, apx. 1877. p.138; pl. 6, fig. 34

Climacograptus cf. caudatus Linnarsson. Sver. Geol. Und. Ser. C, no. 31. 1879. p.18

Climacograptus caudatus Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:358; 1880. 6:22

Climacograptus caudatus Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p.20

Climacograptus caudatus Lapworth. Geol. Mag. Ser. 3. 1889. v. 6, table 11, facing p.68

Climacograptus bicornis var. caudatus Ami. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 2, p.116K

Climacograptus caudatus Gurley. Jour. Geol. 1896. 4:297

Climacograptus caudatus Roemer & Frech. Lethaea Pal. 1897. 1:614. fig. 179

Climacograptus caudatus Ruedemann. N. Y. State Mus. Bul. 42. 1901. p.520 et al.

Climacograptus caudatus Elles & Wood. Monogr. Brit. Grapt. pt 5. 1906. p.202, fig. 133; pl. 27, fig. 7

Description. Synrhabdosomes not observed. Rhabdosome long and slender, attaining a length of 60+ mm (exclusive of virgella) and a width of 2.1+ mm; very narrow at the sicular extremity (.4 mm) and widening very gradually, the full width not being attained until 25 mm from the sicular extremity. Lateral face apparently smooth. Virgella long (32+ mm) and hairlike, in proximal portion (ca. 5 mm) accompanied by a broader sheathlike process. Sicula not observed. Thecae numbering 10 to 12 in 10 mm, middle third of ventral wall concave, inclined at an average angle of 40°; overlapping about one third; distal third slightly inclined. Apertural margin concave, apertural excavation round, occupying one fourth of width of rhabdosome, in length equal to one third the ventral margin. Septum

apparently extending the greater length of rhabdosome. Nemacaulus not observed.

Position and localities. This species has in this State thus far been found only on the west bank of the Hudson river below the power house at Mechanicville in association with Diplogr. foliaceus, Glossogr. quadrimucronatus var. approximatus, Corynoides curtus var. comma and a great number of other fossils, in black shales [*see* Bul. 42, p.520] which are thought to lie close to the base of the Utica shale. In Canada it is, according to Gurley, only known from the Upper Dicellograptus zone at Magog, though Ami has also referred a form from the shale at Quebec to this species. In Great Britain C. caudatus is cited by Lapworth as one of the characteristic graptolites of the Dicranograptus clingani zone of the lower Hartfell beds and of the upper flags of the Ardwell beds in the middle division of the Moffat terrane, of the Trolodden beds of the Girvan district and the Aldress beds (Lower Caradoc) of Wales and the west of England. Its horizon is there above that of Coenograptus gracilis, and hence corresponding to our upper Trenton zone. It also occurs in Ireland and in Scandinavia.

Remarks. The specimens from Mechanicville agree in form and dimensions of rhabdosome and the possession of the long filiform virgella exactly with the original figures of C. caudatus given by Lapworth and the description of the Magog specimens by Gurley.

Fig. 406 Climacograptus caudatus Lapworth. Sicular end showing basal sheath or membrane of virgella. x 5

Climacograptus antiquus Lapworth

Plate 28, figures 28, 29

Climacograptus antiquus Lapworth. Geol. Mag. 1873. 10:134 (*nom. nud.*)

Climacograptus caelatus Lapworth. Cat. West. Scott. Foss. 1876. p.6; pl. 1, fig. 56

Climacograptus caelatus Lapworth. Belfast Nat. Field Club. An. Rep't & Proc. 1877. v. 1, pt 4, p.139; pl. 6, fig. 39

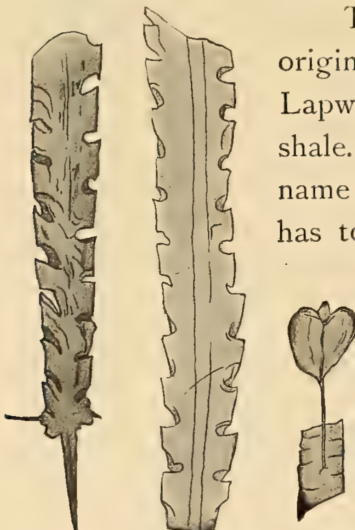
Climacograptus antiquus Lapworth. Roy. Soc. Can. Trans. 1886. v. 5, sec. 4, p.178

Climacograptus cf. antiquus Lapworth. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 1, p.95B

Climacograptus antiquus Gurley. Jour. Geol. 1896. 4:74, 297

Climacograptus caelatus Gurley. *Ibid.* p.76

Climacograptus antiquus Elles & Wood. Monogr. Brit. Grapt. pt 5. 1906. p.199; 200, fig. 130; pl. 27, fig. 4a–e



407 408 409

Fig. 407-9 Climacograptus antiquus Lapworth. Fig. 407 Lapworth's manuscript drawing (x 6½). Fig. 408 Portion of specimen from Indian Territory (x 6). Fig 409 "Vesicle" of specimen from Nevada (x 5). *See also* text figures 21, 22

The name Climacograptus antiquus was originally proposed for a species in a paper read by Lapworth in 1873, on the Diprionidae of the Moffat shale. Only the list of species being published, the name remained a *nomen nudum* and the species as such has to my knowledge never been figured or described. Professor Lapworth has later informed Dr Gurley that the same form has repeatedly been figured by him as C. caelatus [*see* foregoing synonymy]. It is on these figures that the species has to be based until an original description of Scottish material is published.

In his preliminary *Report on Graptolites from the St Lawrence*, Lapworth has cited the species from a number of localities of the zone with Coenograptus gracilis (Normanskill shale) in Canada, and in his manuscript report from the Piñon Range (Summit) in Nevada. Later Gurley has also recognized it with some doubt due to the poor preservation of his material from the equivalent graptolite shales of the novaculite region of Arkansas and we have before us two well preserved specimens from the shales associated with novaculite in the Talihina formation in Indian Territory that seem to accord best with Lapworth's figures.

The last mentioned specimens suggest in their general habit, a coarse Diplograptus euglyphus, but are broader (width 1 mm–1.8 mm), their thecae are arranged more closely (10–11 in 10 mm), their projecting ventral margins separated by smaller intervals and their nemacaulus is broad and straplike. The distal portion of the thecae is slightly inclined to the axis of the rhabdosome, as shown in its ventral margin and the apertural margin is horizontal or slightly inverted. The apertural excavations are well rounded, but shallow, occupying about one fourth to one fifth of the width of the rhabdosome. The sicular extremity of C. caelatus has in common with Lapworth's drawings a stronger development of the virgella and the lateral spines, shown in a fragment.[1]

Climacograptus cf. oligotheca Gurley

Plate 28, figure 27

Climacograpsus oligotheca Gurley. Am. Jour. Geol. 1896. 4: 76

Dr Gurley has described this species from the Upper Dicellograptus zone at Magog, Canada and stated that it is closely allied to C. antiquus, but usually longer and has but 12 to 14 thecae in 25 mm, while C. antiquus has 20 in the same space.

We have not observed this species in the Trenton shales of New York, but find in the collections of the National Museum from Arkansas a specimen which has been labeled C. antiquus var. oligotheca by Dr Gurley, and which fairly well agrees with the description of the Magog species. This is evidently also the C. antiquus ? listed in the same publication [p.297, 305] from Arkansas. The specimen like most of the Arkansas graptolites of that suite is so badly flattened and thinned out that its outlines have become somewhat obscured and no good camera enlargement could be obtained. We give here a figure of the specimen, interest in

[1] From the careful description and excellent figures of C. antiquus since published in the fifth instalment of the *Monograph of British Graptolites*, it becomes apparent that our western specimens are narrower but in all other characters agree well with the British types.

which is still increased by an inflation of the nemacaulus that already begins within the rhabdosome and shows a distinct inclosed virgula.

In its greater length, parallel margins, smaller width and more distant thecae this form has the characteristics of the variety lineatus of C. antiquus distinguished lately in the *Monograph of British Graptolites.*

CRYPTOGRAPTUS Lapworth. 1880

Lapworth defines this genus as follows:

Polypary diprionidian, with attenuated punctate test, subparallel margins, and concavo-convex (?) section. Hydrothecae inclined; lower wall straight or slightly arcuate, outer third forming a distinct excavation, the upper sinus of which is mucronate and oblique; outer wall very short, perpendicular; aperture very oblique, lying wholly within the ventral margin of the polypary.

Type Diplograptus (Cryptograptus) tricornis, Carr.

There is no doubt that this genus represents a well defined group, which though known only by a few species, is easily recognized and has characters which clearly separate it from both Diplograptus and Climacograptus, though with both of the latter it has also some features in common. The most notable of the former characters are the thin periderm of the rhabdosome — on account of which the latter lacks the gloss of the other thick tested graptolites and as a rule has a somewhat hazy appearance — and the deep excavation of the outer margin of the thecae.

The writer's material of the genotype shows that the apertures of the sicula and of the thecae, are provided with stout rings [*see* text fig. 415]. These and the rather strong nemacaulus served evidently to strengthen the otherwise frail periderm.

A remarkable feature are the widely different aspects which the rhabdosomes of Cryptograpti are able to present according to the direction of compression; most notable among these is the difference between the frontal and lateral views. The frontal aspect is broad and presents perfectly straight, parallel lateral margins, while the other, on account of the small inclination and deep excavation of the outer margin of the thecae is much narrower and deeply indented.

To this difference of aspect several errors are evidently due. Thus I have become convinced from the study of the genotype that the two forms

described by me in Memoir 7 as Diplograptus laxus sp. nov. and Cryptograptus antennarius (Hall) are but two aspects of one (the latter) species, one of which alone had been described and figured by Hall. A renewed investigation of the respective Deepkill material has brought out the fact that the specimen reproduced on plate 16, figure 26, *op. cit.* presents both aspects in its upper and lower parts. An enlarged drawing of this specimen is here inserted [text fig. 418.]

It is interesting to note in this connection that the same two aspects of C. antennarius occur in the Beekmantown shales of Arkansas and that Dr Gurley, as an inspection of his material and labels has shown to the writer, has identified the frontal aspect with C. antennarius, the lateral aspect, however, with C. tricornis, and consequently cites both species as being associated in these shales [1890, p.415; 1896, p.299.]

If Diplograptus laxus is united with C. antennarius as a synonym, both American representatives of the genus show such close similarity of their characters that their phylogenetic connection can be hardly gainsaid. The form and closeness of arrangement of the thecae are the same and only the dimensions of the rhabdosomes and of the apertural spines are different. The inflation of the nemacaulus had already been acquired in the Deepkill form and is shown in several specimens of "Diplograptus laxus."

Cryptograptus tricornis (Carruthers)

Plate 28, figures 1–4

Diplograptus tricornis Carruthers. Roy. Phys. Soc. Trans. Edinburgh. 1858. 1:468, fig. 2

Diplograptus tricornis Carruthers. Ann. & Mag. Nat. Hist. 1859. 3:25, fig. 2

Graptolithus marcidus Hall. Pal. N. Y. 1859. 3:515, fig. 1–3

Graptolithus marcidus Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p.58, 59, fig. 1–3

Diplograptus tricornis Carruthers. Geol. Mag. 1868. 5:131, t. 5, fig. 11

Diplograptus etheridgii Hopkinson. Geol. Mag. 1872. 9:504, t. 12, fig. 5

Diplograptus tricornis Hopkinson & Lapworth. Geol. Soc. Quar. Jour. 1875. 31:658, t. 35, fig. 6

Diplograptus tricornis Lapworth. Cat. West. Scott. Foss. 1876. t. 2, fig. 39

Diplograptus tricornis Lapworth. Belfast Nat. Field Club Rep't & Proc. Ser. 2, v. 1, pt 4, apx. 1877. p. 132; pl. 6, fig. 10

Cryptograptus tricornis Lapworth. Ann. & Mag. Nat. Hist. Ser. 5. 1880. 5:171 ff; pl. 5, fig. 27a–27e

Diplograptus marcidus Walcott. Alb. Inst. Trans. v. 10, 1883. (Advance sheet. 1879. p.34)

Diplograptus marcidus ? Whitfield. Jour. Sci. Am. Ser. 3. 1883. 26:380

Cryptograptus tricornis Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:177

Cryptograptus tricornis Lapworth. Can. Geol. Sur. Rep't 1887–88. Ser. 2. 1889. v. 3, pt 1, p.95B

Diplograptus tricornis Ami. Can. Geol. Sur. Rep't 1887–88. Ser. 2. 1889. v. 3, pt 2, p.50K, 117K

Cryptograptus marcidus Dodge. Am. Jour. Sci. Ser. 3. 1890. 40:153

Diplograptus marcidus Walcott. Geol. Soc. Bul. 1890. 1:339

Non Cryptograptus tricornis Gurley. Ark. Geol. Sur. An. Rep't. 1892. 3:415

Cryptograptus tricornis Gurley. Jour. Geol. 1896. 4:298

Cryptograptus tricornis Elles. Geol. Soc. Quar. Jour. 1898. 54:527

Cryptograptus (Idiograptus) tricornis Perner. Etudes sur les Grapt. de Bohême. IIième partie. 1895. p.26; pl. 7, fig. 7–10

Cryptograptus tricornis T. S. Hall. Roy. Soc. Victoria Proc. 1905. v. 18, pt 1, p.21

Cryptograptus tricornis Ami. Geol. Sur. Can. Sum. Rep't 1904. 1905. p.12

Cryptograptus tricornis T. S. Hall. Geol. Sur. Victoria Rec. 1906. v. 1, pt 4, p.275

Description. Rhabdosome short, rarely more than 25 mm long and mostly shorter, narrow, of nearly uniform width throughout (1.3 mm), of rigid appearance, provided with four straight or slightly curved spines at the sicular extremity. Sicula large (2.7 mm) and broad, furnished with a strong apertural ring and four spines. Thecae tubular, numbering 10 to 11 in 10 mm, little inclined (angle of divergence 20°), overlapping one third to

one half; with very prominent mucronate extensions of outer wall; aperture perpendicular to axis of theca, without appendages. Nemacaulus strong, sometimes inflated.

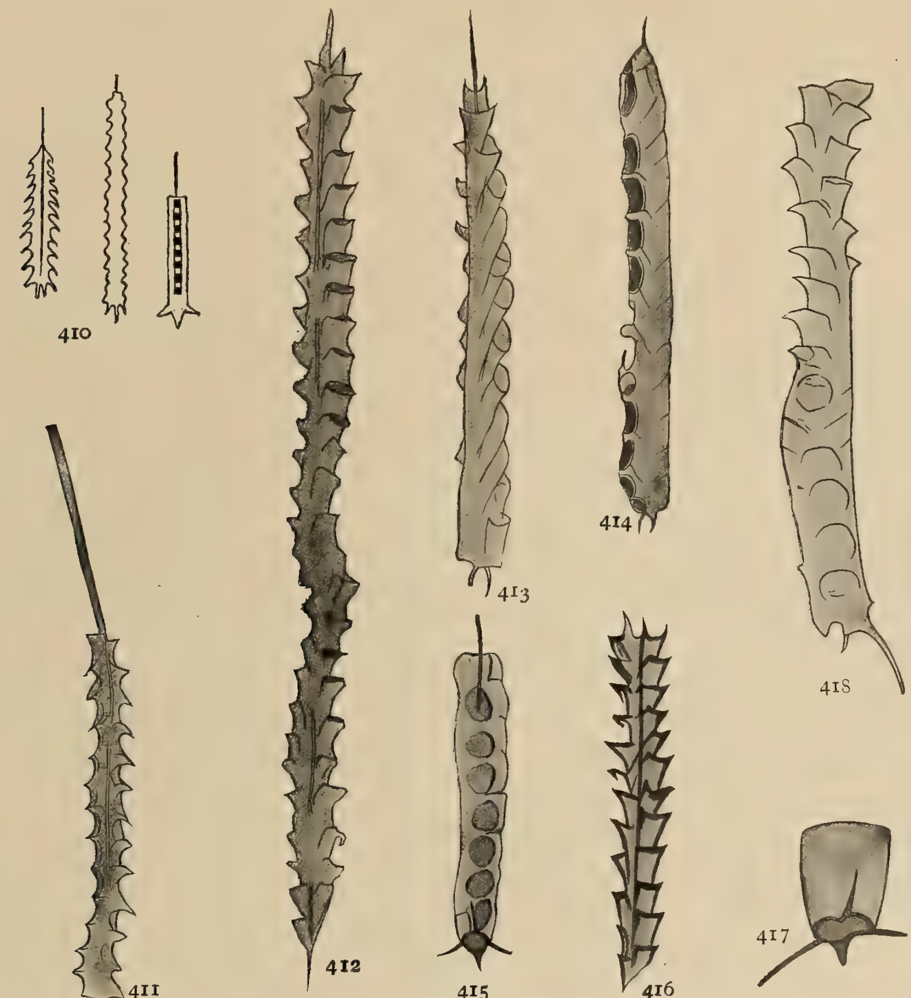


Fig. 410–17 Cryptograptus tricornis (Carruthers). Fig. 410 Copies of Hall's original figures of Graptolithus marcidus. Fig. 411–16 Various aspects of rhabdosomes. Fig. 414 An oblique view, in which the depressed parts of the ventral walls look like apertures. Fig. 415 A frontal view in which the aperture of the sicula and the four sicular spines are seen. Fig. 416 A partly macerated specimen, in which the marginal ledges are shown. The originals of figures 411 and 416 are from Speigletown, N. Y. and represent a slightly different variety; those of the others are from Glenmont, N. Y. Fig. 417 Aperture of sicula. Fig. 418 Type of Memoir 7, plate 16, figure 26, redrawn to show the appearance of a Cryptograptus antennarius in the lower half, and that of a Diplograptus laxus in the upper. All enlarged about x 5, except figure 417, which is enlarged x 7

Position and localities. Lapworth records this species as "very numerous in the Glenkiln and lower Hartfell shales of the south of Scotland," and

as also occurring in Ireland. Hall found it in considerable number in the Normanskill shale at the Normanskill. The writer has observed it in nearly all of the many outcrops of the Normanskill shale (Dicellograptus zone) in the slate belt of New York, often in profusion, especially so at Glenmont, south of Albany; at Mt Moreno near Hudson and in localities in Washington county; and in a mutation [*see* below] also in beds transitional from the Trenton to the Utica shale at Van Schaick island below Cohoes, in association with Utica fossils (Climacograptus putillus, Leptobolus insignis, Schizocrania filosa). In Canada Ami has found it in Normanskill beds at Point Levis near Quebec and Lapworth has recognized it in collections from the Upper Trenton zone at Quebec. Lately Ami has also announced its occurrence in New Brunswick. Gurley cites it further from the beds at Mystic and Magog in Canada. In the west of the continent it occurs, according to Lapworth, in beds at the Kicking Horse pass, and at Dease river, British Columbia. Gurley has reported it from the "Upper Calciferous zones" of Arkansas and Nevada. T. S. Hall has this year described it from Victoria, Australia, and Perner has identified a form from d 1γ in Bohemia with Carruthers's species.

It is evident from these citations that this small peculiar graptolite possessed not only a considerable range and may have extended from the Chazy formation to the base of the Utica, but was also well established in Trenton time in both the Atlantic and Pacific oceanic basins, and their border seas, as the Appalachian and Bohemian-Mediterranean basins. I have not seen it cited from the Baltic basin, but doubt that it was absent there.

Remarks. This most remarkable graptolite has baffled the attempts of paleontologists to elaborate its obscure structure and led to the erection of various species, until Lapworth succeeded in unraveling the mystery and described the true form of the thecae.[1] We can do no better than copy his description [1880, p.173 f] here:

[1] A peculiar variety [*see* fig. 411, 416] characterized by thinner rhabdosome and somewhat closer arrangement of the thecae (12–13 thecae in 10 mm) has been observed in an outcrop of Normanskill shale near Speigletown north of Troy.

The hydrothecae have features common to those of both *Diplograptus* and *Climacograptus.* They are steeply inclined and have an oblique aperture, as in the former, while their apertural margin opens wholly within the ventral margin of the polypary, in a distinct excavation, as in the latter genus. In the obverse (?) aspect [fig. 27e] their walls appear to be elegantly curved, and there is an appearance of distal expansion. In the reverse aspect the walls are almost straight, and the thecae are of equal width throughout. These diverse appearances are, in all probability, a result of the original form of the polypary, which was somewhat concavo-convex previously to compression.

The outer portion of each hydrotheca forming the wrinkled-looking ventral margin of the polypary is composed of three divisions. The lowest division is a distinct excavation (visible directly only in subscalariform views) which overhangs the aperture of the theca immediately below. The outer sinus of this "excavation" is prolonged, as in many species of *Climacograptus*, into a mucronate extension, oblique, and occasionally of remarkable length. The middle division is short and approximately perpendicular, as in *Climacograptus.* The final division is formed by the line of the apertural margin. The latter is very oblique with respect to the axis of the polypary, but, as in the majority of other Diprionida, is almost at right angles to the normal direction of the hydrotheca. It lies wholly within the ventral boundary of the polypary, and is visible in very rare cases. As pointed out by Mr Hopkinson, the test in these forms is of remarkable tenuity. It is generally preserved as a mere stain, very different from the stout chitinous film representing the commoner diprionidian forms with which it is usually associated. In the Girvan examples the test appears to have been more or less punctate.

Lapworth points out that Hall while not attempting to describe the shape of the thecae, figures a specimen [*see* text fig. 410] in which the thecae are inverted in position, i. e. the apertures opening towards the sicular end. This abnormal aspect is due to the recurving direction of the oblique outer mucronate extensions of the thecae and well shown in the specimen reproduced in text figure 411. The broadly oval to subcircular apertures themselves are shown in oblique compression in figure 413, in frontal view in figure 415. In the latter specimen the attenuated punctate test contrasts with the solid weltlike marginal thickenings of the apertures which appear as circular rings in the compressed specimen. The stoutest ring surrounds the aperture of the sicula [*see* text fig. 415, 417]. This sicu-

lar ring is the bearer of four slightly curved spines, three of which are, as a rule, alone seen in a compressed specimen, the fourth falling into the periderm of the rhabdosome. These three easily visible spines have given the species its name, which is thus seen to be a misnomer. One of these spines is in fig. 419, 420 observed to extend into the sicula and therefore to correspond to the virgella of the diplograptids.

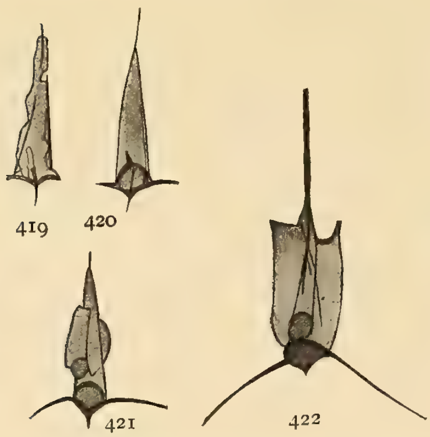


Fig. 419–22 Cryptograptus tricornis mut. insectiformis nov. Fig. 419, 420 Siculae seen from opposite sides showing the apertural ring, virgella and spines. Fig. 421, 422 Young rhabdosomes. All enlarged x 5, except figure 422, which is enlarged x 7

The first theca does not seem to grow first in apertural direction, as in Diplograptus and Climacograptus but directly upward [*see* fig. 422].

In a few cases the nemacaulus is seen to be inflated [*see* pl. 28, fig. 4] and sometimes it is broad and bandlike.

In a subzone, observed by the writer on Van Schaick island [*see* p.31], which is transitional from the Trenton shale to the Utica shale, a mutation appears, that in its whole character denotes the decadence and approaching extinction of the species. This may be described as

Cryptograptus tricornis mut. **insectiformis** nov.

Plate 28, figure 5

The rhabdosome is short (8–9 mm long), rounded and broadest at the sicular end (1.6 mm) and somewhat abruptly contracted to 1.2 mm, after the first third of its length. The thecae are very closely arranged (16 in 10 mm), the sicular spines strongly curved.

It will be seen that this mutation differs from the type of the species in its shorter and more compact form, more closely arranged thecae and an abrupt diminution in width from that of the typical form in the first half of the rhabdosome. While it bears some similarity to young specimens of the typical form, the greater closeness in the arrangement of the thecae and the

constancy of its differential characters in all specimens from the same horizon leave no doubt that we have a mature though dwarfed form before us.

Family MONOGRAPTIDAE Lapworth

MONOGRAPTUS Geinitz, em. Jaekel et Frech

While the genus Monograptus is so profusely represented in the Siluric of Europe that not only a great number of species have been distinguished but its distribution has also been the means of the elaboration of a most refined system of Siluric horizons, North America has, besides a form in the arctic North, yielded but two species, one in the Clinton beds of New York and one in the Siluric of Maine, and both of these are hardly more than mutations of the most common and best known European species, M. priodon Bronn. We can, therefore, restrict ourselves to a consideration of the group of Monograpti of which M. priodon is the representative.

423 424

Fig. 423, 424 Copies of Emmons's figures of Monograpsus elegans and Monograpsus rectus, respectively

The genus Monograptus, as originally conceived (Lomatoceras Bronn, Monoprion Barrande and Graptolithus of some authors) has been derived through forms of Dimorphograptus from Diplograptus and Climacograptus, by the reduction of the biserial arrangement of their thecae to a uniserial one. In correspondence to this origin of the genus the sicula occupies the most distal point of the rhabdosome and the thecae grow in a reversed direction, climbing up along the nemacaulus as in Diplograptus and Climacograptus. This position of the sicula and the growth direction of the first theca (first downward and then upward) are well shown in some of our Clinton specimens [*see* fig. 428].

The form of the thecae was extremely diverse in the genus Monograptus as originally conceived and has led to the distinction of several genera. Those with the thecae of a Climacograptus have been united by Frech [1897, p.621] under Monoclimacis; and Jaekel had previously placed the forms with hood or coverlike ventral margin of the aperture under

Pomatograptus and those with plain thecae of the Diplograptus type under Pristiograptus. Frech has distinguished four groups among the Monograpti with distally prolonged apertures and retains all four (including Pomatograptus) in Monograptus, stating that they are united by transitional forms. M. priodon [*see* text fig. 425] is the type of the first group with trunklike prolonged apertures. The form of the apertural prolongations is distinctly shown in some pyritized specimens of M. clintonensis from Rochester [*see* fig. 427, *also* the sections 429, 430].

Emmons's species "Monograpsus rectus" and "M. elegans" [*see* text fig. 423, 424] are undeterminable, the types having been lost, but undoubtedly based on fragments of Didymograptus and noted under that genus [*see* p.255, 256].

Monograptus clintonensis (Hall)

Plate 29, figure 1

Graptolithus clintonensis Hall. Geol. N. Y. 4th Dist. 1843. p.74; 72, fig. 12

Graptolithus clintonensis Hall. Pal. N. Y. 1851. 2:39; pl. A 17, fig. 1

Monograptus clintonensis Geinitz. Die Graptolithen. 1852. p.58

Graptolithus clintonensis Hall. Can. Org. Rem. Dec. 2. 1859. p.25, 27, 29; pl. B, fig. 1-4

Graptolithus clintonensis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. 1867. p.195, 197; pl. 1, fig. 1-4

Lagenograptus clintonensis Hall. N. Y. State Cab. Nat. Hist. 20th An. Rep't. Rev. ed. 1870. p.261; pl. 1, fig. 1-4

Monograptus priodon Linnarsson. Ofv. af Kongl. Vetens. Akad. Förh. No. 5. 1879. p.12

Monograptus clintonensis Lapworth. Geol. Mag. 1880. 7:68

Monograptus clintonensis Geinitz. Mitth. kön. min.-geol.-praeh. Mus. Dresden. 1890. 9 Heft, p.19

Lomatoceras clintonense Gurley. Jour. Geol. 1896. 4:308

Monograptus priodon Bronn mut. clintonensis (Hall) Frech. Lethaea Pal 1897. 1:641

Description. Rhabdosome obviously very long; for fragments 80 mm long and without appreciable change in width and others 2 mm wide indicate, in view of the slow rate of growth of the rhabdosomes [*see* fig. 428] a considerable distance of the fragments from the sicular extremity; very

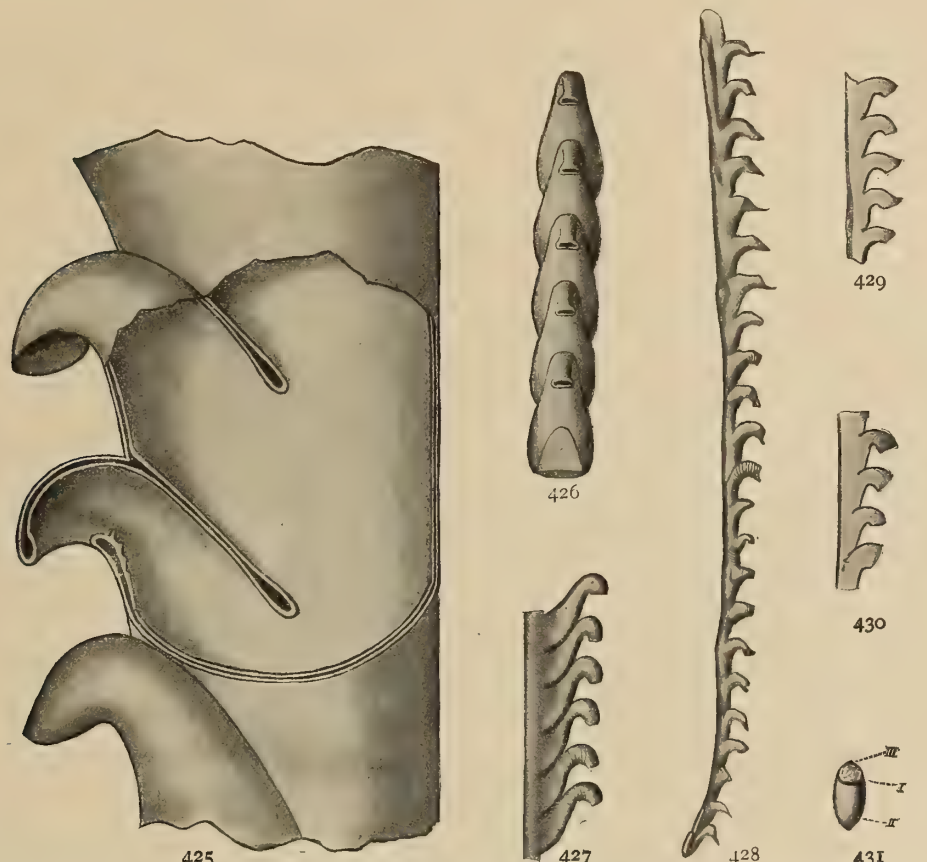


Fig. 425 Monograptus priodon Bronn (x 28). Copy of restoration from Perner, for comparison with M. clintonensis and to show structure of rhabdosome of Monograptus. Fig. 426–31 Monograptus clintonensis (Hall). Fig. 426 Copy of one of Hall's figures in Canadian Organic Remains. Fig. 427 Mature portion of pyritized rhabdosome, showing form of thecae. Fig. 428 Sicular portion of partly pyritized rhabdosome, showing sicula, recurving of first theca and shape of earlier thecae. Fig. 429, 430 Thin sections through pyritized specimens; figure 429 near surface; figure 430 approximately through median plane. Fig. 431 Transverse section of pyritized specimen: I = common canal, II = theca seen from below, III = nemacaulus and virgula. x 5

slender and nearly straight, with a short, slight curvature of the sicular end. Width at sicular extremity .3 mm; that of mature parts 2 mm. Sicula small (1.5 mm) and slender; furnished with an apertural spine. First theca originating at beginning of last third of sicula and becoming

reversed in direction opposite the aperture of the sicula. Early thecae adhering for two thirds of their length to the common canal, projecting horizontally with their last third and bending slightly in sicular direction with their apertural portion; numbering 11 to 12 in 10 mm; their apertures furnished with a short, stout, horizontal apertural mucro; those of the adult parts overlapping two thirds of their length, inclined at an angle of 30°, numbering 9 to 10 in 10 mm; their free, apertural portion sharply recurved so as to become parallel to the axis of the rhabdosome and contracted towards the aperture; the latter horizontal, occupying but one fifth the width of the rhabdosome. Synrhabdosomes and a nemacaulus have not been observed.

Position and localities. Hall in his original description has recorded this species "as very abundant in the upper green shale" of the Clinton group at Sodus, Wayne co., and also as occurring in the eastern part of Williamson and in the banks of the Genesee river at Rochester. Other localities of the Clinton belt, where the upper shales are exposed, as Palmer's Glen near Rochester, have also furnished this graptolite in abundance. In the course of the investigation of the stratigraphy of the Clinton group, now in progress, the exact horizon of this and other Clinton graptolites will be determined.

Remarks. The similarity between M. priodon and M. clintonensis is so great that several authors inclined to make the latter a synonym of the former; e. g. Linnarsson [1879] who however remarked that in our present state of knowledge they are most conveniently regarded as distinct. Lapworth, on the other hand [1880] states that he is sure that their individual distinctness will eventually be placed beyond question. Frech [*loc. cit.*], again, has considered our form as a mere mutation of priodon, from which it is said to differ by the tubular prolongation and straight truncation of the thecae, and also Dr Gurley has stated in a manuscript note "that its resemblance to L. priodon is so close as practically to amount to identity." The general similarity between the two forms is indeed considerable, still there are important differences; those already

pointed out by Frech would place the form close to M. priodon var. rimatus Perner, which however, has shorter apertural tubes. A comparison of Perner's exact camera drawing of the earliest portion of the rhabdosome [*see his* pt 3, sect. b, p.2, fig. 1] of a specimen in relief, with a like drawing of a pyritized specimen of our material [*see* text fig. 428] brings out at once the fact of the different rate of growth of that portion; that of M. priodon attaining very rapidly its full width and that of M. clintonensis growing very gradually.

The early thecae possess distinct apertural spines [*see* fig. 428], a feature not observed in any of the varieties and mutations of M. priodon with the exception of the variety flemingi (Lapworth) Frech. To the latter, which, however, is considered by Lapworth as a distinct species, the immature thecae of our form would seem to approach most in their apertural characters while the adult thecae are those of a priodon. On account of the differences in the early rhabdosome, here mentioned, we have preferred to recognize M. clintonensis as a distinct species of the halli or priodon group.

The two sections through pyritized adult thecae here introduced [fig. 429, 430] are best suited to show the true form of the thecae and a comparison of the figures with the section through a typical M. priodon given by Perner [*see* text fig. 425] demonstrates the difference in their thecal forms.

While there exists a distinct differentiation of the earlier and later thecae of the rhabdosome, it is by no means so marked as Hall's figures [*loc. cit.* pl. B, fig. 1, 2] and description [1859, p.29] would suggest. Hall states that in the mature thecae the aperture is directed downward and in the less mature upward, the latter possessing an angular aperture. The aperture is however directed downward in all thecae and the difference is only one of degree of development of the apertural tube, the latter gaining gradually in length with the growth of the rhabdosome. The triangular aspect of the early thecae in the pyritized specimens is largely due to the failure of the thin tubular distal portion of the thecae to become pyritized.

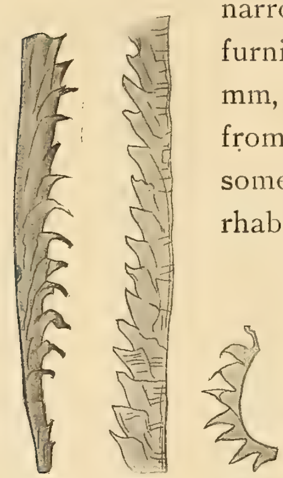
Monograptus priodon (Bronn) mut. **chapmanensis** nov.

Plate 29, figure 2

cf. Monograptus clintonensis (Hall) Dodge & Beecher. Am. Jour. Sci. Ser. 3. 1892. 43:412 f

Monograptus (Graptolithus clintonensis) priodon H. S. Williams. U. S. Geol. Sur. Bul. no. 165. 1900. p.46

Description. Rhabdosome straight, of medium size (largest fragment observed 60 mm long and 2.6 mm wide). Sicula not observed, sicular end narrow (.4 mm), rapidly expanding (within 10 mm to 1 mm), furnished with virgella. Thecae numbering 11 to 14 in 10 mm, normally 11; inclined at an angle of 40°, overlapping from one third to one half their length; their free portion somewhat abruptly contracting to a recurving tube. Synrhabdosome and nemacaulus not observed.



432 433 434

Fig. 432–433 Monograptus priodon mut. chapmanensis nov. Fig. 432 Sicular end. Fig. 433 Mature portion of rhabdosome. Fig. 434 Fragment of an undescribed Monograptid from the Aroostook limestone, Caribou, Me.

Position and locality. Collected by Mr Olof O. Nylander in a brown micaceous sandstone in the northwestern part of the Chapman Plantation in Aroostook county, Me. It is there not associated with any other graptolites.

Remarks. The preservation of this form is not so perfect that all doubt as to its exact identification would be removed. Above all the tubular distal portions are only preserved in two specimens [*see* fig. 432] and there so incompletely that the aspect of the form is more that of a M. riccartoensis, with wide aperture and everted denticle. In nearly all cases the rhabdosome has been fractured so obliquely that the aspect reproduced in fig. 433 and which is not suggestive of a M. priodon at all results. A few of the tubular portions are, however, distinctly visible when the rock is placed under water. While these would permit the reference of the form as well to M. priodon as to M. clintonensis, we have, on account of the quite rapid expansion and coarser form of the rhabdosome rather placed it with the former than the latter

species. The closer arrangement and somewhat different inclination of the thecae indicate a differentiation here recognized as only of varietal or mutational character but possibly of specific importance.

Dodge and Beecher have listed a "M. clintonensis" from the shales of North Haven in Penobscot bay, Maine, which is possibly identical with this variety. The M. priodon of Williams comes from the same bed and locality as our types of the var. chapmanensis and can, therefore, be considered with certainty as belonging to the latter.

Monograptus beecheri Girty

Plate 29, figure 3

Monograptus beecheri Girty. N. Y. State Geol. 14th An. Rep't. 1895. p.288; pl. 4, fig. 3-15

Rastrites beecheri Frech. Lethaea Pal. 1897. 2:116.

Girty's elaborate description of this interesting species is:

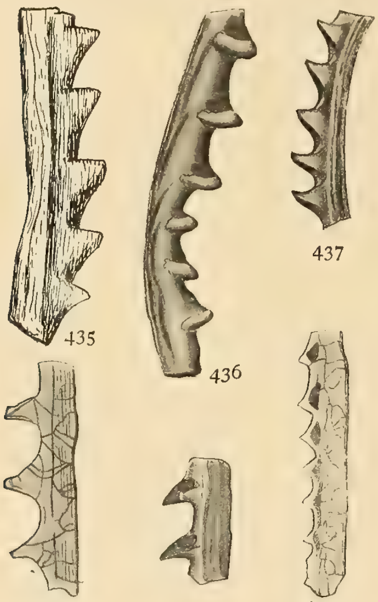
Stipe linear, minute, with a carination on either side. Surface marked by fine longitudinal striae, which are not continuous. Denticulations about the same width as the stipe, acute, distant. It is not known whether the stipe is simple or branched.

This species of Monograptus is interesting, not alone as the first example of the genus reported from the Lower Helderberg rocks, but also as the last known representative of this characteristic Silurian genus. Its presence here is important in its bearing upon the position of the Lower Helderberg group in the geological scale, for similar forms have been found in the earliest Devonian faunas of Germany.

The stipe is cylindrical, sometimes tetragonally prismatic. It is hollow, with thick walls, crossed at intervals by tabulae, one for each serration, which bound the zooidal habitations. On opposite sides, there are projecting ridges, or costae, the plane of the latter being at right angles to the plane of the serrations. Besides the costae, there are often fine longitudinal grooves or striae. The teeth are rather distant; the upper side is sometimes at right angles to the stipe, at others acutely inclined to it. The upper surface is somewhat flattened and is pierced by circular or elliptical zooidal openings, situated well toward the stipe. The under surface of the teeth is sometimes flattened, sometimes rounded, the flattened examples at least being provided with a median ridge. The specimens observed are all fragmentary, and the nature of the sicula has not been ascertained. No indications of branching have been noticed, but the zoarium may be bifurcated or even ramose.

Horizon. Shaly limestone, Indian Ladder, Helderberg mountains.

By way of bringing this description in uniformity with the others in this monograph, we add the following data which we take from the type material now in Yale University Museum and kindly forwarded to us by Professor Schuchert: The fragments indicate an extremely minute rhabdosome, their length is but little more than 1 mm, their width, inclusive of denticles, not quite .2 mm, and the thecae number 70 to 80 in 10 mm; the form is hence of exceptionally small dimensions and would seem to indicate by this feature its position as last decadent epigone of the once mighty family of Monograptidi. The thecae are three and one half times as long as wide, overlap about one third their length and are inclined not more than 10° to the axis of the rhabdosome. The denticle is slightly recurved, and acutely pointed, somewhat clawlike. The aperture is small, apparently restricted to the inner corner. The surface is longitudinally striated or even wrinkled and costate, while the transverse growth lines, so distinct on most graptolites, could not be made out. It seems hence that the periderm was not only relatively quite thick, but also furnished with external excrescences not observed in the Siluric graptolites. The branch presents therefore an aspect which is liable to suggest another taxonomic position than that among the graptolites.



439 438 440

Fig. 435–40 Monograptus beecheri Girty. Fig. 435 Copy of one of Girty's original drawings showing form of denticles. Fig. 436, 437, 438 Redrawings of some of the types. Fig. 439, 440 Thin sections of typical specimens. Fig. 435 enlarged x 6; the others x 5

The facts which combined appear to dispute the graptolitic nature of these bodies are: their extremely small size, as compared with that of other Monograpti; the indistinctness of the apertures; the strong longitudinal carinations and striae; the absence of transverse growth lines; and finally their Devonic horizon. The small size, form and luster of the deep black bodies are quite apt to suggest that they were fragments of worm

jaws or possibly of conodonts which according to Hinde are found in the Chazy rocks with the same black luster. Thin sections made through a few specimens and comparison of the same with sections of worm jaws and conodonts have, however, shown the impossibility of referring the bodies to either of the latter since they are not solid as these but consist of an exterior periderm and an interior calcite filling [*see* fig. 440]. But these sections have also demonstrated the absence of internal thecal walls — except as low internal ridges of the outer wall — another feature that distinguishes the form from the Monograpti.

On the other hand, the form of the fragments is well comparable with that of Monograpti, as e. g. M. vomerinus; the small size of the apertures, which however in some specimens are well discernible, is also in line with that of certain Monograpti and if it is further considered that the bodies can not be readily referred to any other class of fossil organisms, it appears as the most satisfactory course to attempt to reconcile the refractory characters of the form with the structure of the graptolites. It seems then that all these features can be considered as forming one group, indicative of the paracmic nature of the species. Since also a Monograptus is reported from the Lower Devonic of Bohemia, the genus appears to have actually persisted into that era and its representatives there would naturally be expected to exhibit characters not observed where the genus was culminating. The extremely small size of the branches, the relatively thick periderm and its external carinations and ridges and the restriction of the size of the apertures are all readily explained as resulting from the unfavorable conditions under which this gerontic form was struggling.

The reduction of the internal thecal wall to ridges, and the obscuration of the transverse growth lines (for fine transverse lines have been distinctly seen by the writer in the depressions between the carinations) are very likely secondary characters, the former resulting from the small size of the whole branches and the latter from the formation of external excrescences.

Since only small fragments of M. beecheri are known and neither

the sicula nor the number of types of thecae in one rhabdosome nor other important characters have as yet been observed, it would be futile to attempt a positive reference to one of the groups of the genus Monograptus recognized in Europe. The thecae are those of a Monograptus s. str. and resemble somewhat those of M. vomerinus Nicholson as figured by Perner [1899, p. 18], from specimens preserved in relief.

Frech [*loc. cit.*] has cited this form as a Rastrites. Although the specimens when embedded in limestone, on account of the more or less complete covering of the branches and the resulting prominence of the horizontal denticles, resemble a Rastrites more than anything else, Girty's type specimens which are entirely free, leave no doubt that the thecae are not projecting as in Rastrites at right angles from a thin common canal, but are normally overlapping as in true Monograpti. To bring out this and several other features of the species not well shown in Girty's otherwise correct figures, I have redrawn several of the types in somewhat different positions. The original of figure 436 [same as pl. 4, fig. 8 of Girty] shows distinctly the thecal walls and what appear to be the apertures. The perisarc of the denticles is broken off and they appear for this reason as very blunt processes. Figure 437 [pl. 4, fig. 4 of original drawings] brings out distinctly the acutely pointed form of the denticles, and figure 438 [pl. 4, fig. 12, *ibid.*] which gives a somewhat oblique view shows the relatively small apertures and the angular sides of the distal parts of the thecae.

The "tabulae" which according to Girty's observations cross the coensarcal canal at intervals, one for each serration [*see* pl. 4, fig. 3 of original paper], and as stated in the explanation of plate 4, are seen in translucent specimens, could not be found by the writer in those specimens which by the loss of the perisarc have become translucent. They would represent an interesting and novel feature whose existence, though asserted before for certain graptolites [Hopkinson], has not been verified. Thin sections exhibit, however, numerous cracks of the calcite filling which passing in some parts of the branches nearly straight transverse, are apt to produce the impression of tabulae [*see* fig. 439].

The chief interest of this dwarfed straggler centers about its geologic position. It not only represents the last appearance of the important genus Monograptus but also of all Graptoloidea or graptolites proper, only Dendroidea being observed thereafter. Since also a small Monograptus has been obtained in the lowest Bohemian Devonic (F_1), the occurrence of this Monograptus could not be used as argument for the Siluric age of the Lower Helderberg beds; while, on the other hand, after the closing of the Hercynian controversy and the relegation of the Hartz graptolite shales to the Siluric, it still serves to emphasize the fact that, after all, Monograptus persisted into the Devonic era.

CYRTOGRAPTUS Carruthers

The character distinguishing Cyrtograptus from Monograptus is the presence of secondary branches on one side of the mostly curiously curved stipes. This offshoot of the Monograptidae was very short-lived; it is restricted to the middle Siluric, but there so prominent that no less than four zones are characterized by its species.

The Siluric rocks of North America have not before furnished any representatives of this peculiar genus and the discovery of a species in the Western Niagaran may eventually become of some interest in connection with paleogeographic problems.

Cyrtograptus ulrichi sp. nov.[1]

Plate 29, figure 4

The collection of graptolites, kindly placed at my disposal by Dr Ulrich, contains three small slabs of a dark chocolate-brown limestone that are densely covered with middle sized, slender, gracefully curved branches of a graptolite, totally distinct in form from all other American graptolites.

[1] Named in honor of Dr E. O. Ulrich to whom we owe the discovery or rather rediscovery of this most interesting graptolite. This indefatigable geologist, on reading that Shumard over 50 years ago noted the presence of a graptolite in the Bainbridge section, determined to locate and collect it. Shumard's section and statement that one of the layers is full of a graptolite is published on page 262 of the *Report of Missouri for 1855–71.*

I see in these the detached secondary branches of a Cyrtograptus, although there has not been found a complete rhabdosome which would give undisputable evidence of the generic position of the form. The absence of a sicula at the narrow extremity of the bodies, however, demonstrates their incomplete condition or their nature of broken-off branches of a larger rhabdosome, thereby refuting a possible reference to Monograptus, while the peculiar sickle-shaped form, the equal size of the fossils and their geologic horizon (late Niagaran), all point to a reference to Cyrtograptus as the most satisfactory one.

441

442 443

Fig. 441 Cyrtograptus murchisoni Carruthers. Copy from Perner to show form of rhabdosome of Cyrtograptus. Fig. 442, 443 Cyrtograptus ulrichi sp. nov. Portions of branches, enlarged x 5

Description. Branches medium sized (30–40 mm), falciform, most strongly curved at the proximal end, and becoming less curved and sometimes nearly straight toward the distal extremity; very narrow (.2 mm) at the beginning, but gradually (within 20–25 mm) attaining their full width (1.4 mm–2 mm), which is then maintained. Thecae numbering 8 to 10 in 10 mm; broad and relatively short (two and one half times as long as wide), but possibly not preserved in full length, inclined at 20°, overlapping two thirds their length; without spines; not contracted towards the aperture which is normal to the axis of the theca and straight; ventral margin also straight.

Position and locality. Upper part of Bainbridge limestone (corre-

sponding to late Niagaran), Bainbridge, Cape Girardeau co., Mo. Types in Ulrich collection.

Remarks. Since the Niagaran and its equivalents have as yet not furnished any true graptolites and the two Clinton graptolites are the only representatives in America of the rich European Monograptus fauna, the finding of another Monograptid in the Siluric is of no little interest, and if the form here described is indeed a Cyrtograptus, as we feel sure it is, its importance is still enhanced as representing the occurrence in the North American continental sea of one of the most peculiar genera of the later Monograptids, hitherto only known from the Atlantic, Bohemian and Baltic basins.

In view of the fact that the species of Cyrtograptus furnish some of the most important index fossils of the graptolite zones of the Siluric, it seemed further desirable to institute a closer comparison with the European species and by a possible identification obtain a graptolitic datum plane for our Siluric. While our form as judged from the secondary branches alone, is specifically distinct from all of the European forms, it is obviously very closely related to C. lundgreni Tullberg [1883, p.39] from the Cyrtograptus shale of Scania and since that species is restricted to the zone with C. carruthersi — the uppermost zone of the middle Siluric — both occur in approximately equivalent beds and may be vicarious forms. While the Scanian and Missourian species have the general form of the branches and that of the thecae, especially also their lack of prominence and their inclination in common, the branch of the American form is notably narrower in its proximal portion and wider in the distal one and also shorter.

Since the thecae of Cyrtograptus are quite variable in form in different portions of the rhabdosome, as Frech has pointed out, a perfect identification is impossible without a knowledge of the thecae of the main stem.

The before mentioned lack of prominence of the thecae is a marked feature of the branches; in fact, the thecae, largely on account of their small inclination and great overlap are so little projecting that of all the many branches visible on the slab, only two or three were suitable for

camera drawing and all the others presented scalariform aspects and nearly smooth margins. There is little doubt that this mode of preservation is also to a great extent due to the curvature of the branches which is such that they rarely come to rest upon their lateral faces.

Family RETIOLITIDAE Lapworth

RETIOGRAPTUS Hall

A sketch of the history of this genus has been given in Memoir 7 [p.732] and one of the three species which have been referred to Retiograptus (R. tentaculatus) has been described more fully from material obtained in the Deepkill shale. In the present publication the two remaining species (R. eucharis and R. geinitzianus) are redescribed, the New York rocks having furnished specimens which much surpass the types in completeness of preservation. This new material has shown that the first named of the two species was originally misunderstood in regard to the arrangement of the thecae which is described as being rectangular while in fact, it is as in Diplograptus, and the exterior aspect of the thecae is typically diplograptid. We have for reasons given before, placed the form under Glossograptus. It has also been found that in the other species, R. geinitzianus, the structure of the skeleton, especially the character of the axes, is most suggestive of Glossograptus. No corresponding structure has as yet been observed in the genotype of Retiograptus, R. tentaculatus, but the great external similarity of the latter to R. geinitzianus suggests that it may possess it. In that case all the forms here mentioned will be finally associated in a subdivision of Glossograptus. With this view in mind we have, for the present, left R. geinitzianus in its original place.

The citation of the rectangular arrangement of the thecae, as one of the principal characters of the genus is, as here shown, based on misconception. In G. (?) eucharis a certain preservation facies produces the aspect and in the other two species the horizontal parietal ledges are responsible for the apparent presence of horizontal thecal walls.

Retiograptus geinitzianus Hall

Plate 29, figures 5, 6 ; plate 31, figures 9–17

Reteograptus geinitzianus Hall. Pal. N. Y. 1859. 3:518, figure

Retograptus barrandi Hall. N. Y. State Cab. Nat. Hist. 13th An. Rep't. 1860. p.61, figure

Clathrograptus geinitzianus Lapworth. Ann. & Mag. Nat. Hist. 1880. 5:22

Retiograptus geinitzianus Walcott. Alb. Inst. Trans. v. 10, 1883. (Advance sheets. 1879. p.35)

Retiograptus barrandei et R. geinitzianus Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Reteograptus geinitzianus Gurley. Jour. Geol. 1896. 4:80

Reteograptus ? geinitzianus Frech. Leth. Pal. 1897. 1:608

Clathrograptus cf. geinitzianus T. S. Hall. Geol. Sur. N. S. Wales Rec. 1902. v. 7, pt 2, p.7; pl. 14, fig. 5

Reteograptus geinitzianus Weller. Geol. Sur. N. J. Pal. 1902. 3:53

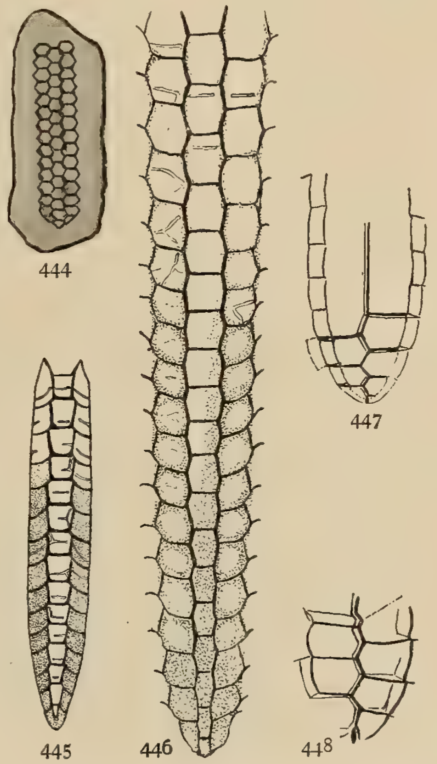


Fig. 444–48 Retiograptus geinitzianus Hall. Fig. 444 Copy of Hall's original figure. Fig. 445–48 Gurley's manuscript drawings. Fig. 445 Central (scalariform) view of rhabdosome (x 4). Fig. 446 Specimen showing the apparent apertural spines. Fig, 447, 448 Sicular portions. Figure 445 is enlarged x 4 ; figures 446 to 448, x 6

To Hall this species was known only as a fragment consisting of three rows of hexagonal meshes [*see* text fig. 444]. Dr Gurley obtained in the Normanskill shale at Stockport some material in particularly favorable preservation and thereby succeeded in making out the structure of the skeleton. He has published in 1896 a full account of his discovery. We have found still better material in our collection from Schodack Landing, N. Y. and Prof. Bishop's from Chatham, N. Y., which permits the elucidation of points left unexplained by Gurley. To give the reader a full presentation of the complex structure of this form we have here inserted besides Dr Gurley's published description his original drawings, heretofore

unpublished, which were found with the manuscript and have added our own observations as well as a number of figures, explanatory of the latter [*see* pl. 31].

Dr Gurley has given the following description:

The polypary in this species is parallel-sided blunt-fusiform, and consists of skeleton and periderm. The skeleton shows, at and imbedded in its base a body apparently a sicula, flanked on either side by a spine which is directed obliquely upward. Two virgulas are present, each zigzagged in the basal expanding portion of the polypary, straight in the middle (parallel-sided) portion, and (?) again zigzagged in the upper contracting part. From the convex angles of the zigzagged, and at intervals from the straight portion of the virgula, a parietal ledge [1] runs in each lateral wall to the ventral margin, where it undergoes an abrupt deflection downward to the parietal ledge of the theca next below, to which it appears to connect just before (i. e., at a point on the lateral surface just within the ventral margin) that ledge reaches its point of downward deflection. At the latter point a mouth ledge connects the parietal ledge with its fellow on the opposite side. These three chitinous threads (the horizontal limb of the parietal ledge, the vertical limb of the same and the mouth ledge), all meet at the point of deflection with rounded edges, and together form the rim of the mouth opening, which is thus somewhat squarish or slightly trapezoidal. I have seen nothing corresponding to the inner cross-ledges and the material furnishes no data for an opinion *pro* or *con* as to the existence of any interthecal partition planes.

The periderm consists of three, rarely only two, longitudinal series of meshes of a subrhomboidal shape which alternate in adjacent rows, and give off from the middle points of the meshes of the outer rows (the rows along the ventral margin) short, stout spines which are the mouth ledges crushed V-shape. The relation of the three rows of peridermal meshes to the skeleton is not known. The parietal ledges form the upper and lower borders of the meshes, and are deflected inwards (i. e., into the intra-polyparial space) to their virgular connection at the inner borders of the outer rows of meshes (?). The meshes are covered by a membrane which is markedly thinner in the center of the mesh.

The form of the rhabdosome and the relation of the three rows of peridermal meshes to the skeleton alluded to above is made clear by plate 31, figure 11. The lateral faces were flat and fully covered by the continuous

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[1] I here follow the nomenclature of Holm [Bihang til kongl. Sv. Vet.-Akad. Handl. 1890, XVI, no. 7].

peridermal layer, at least in the sicular moiety of the rhabdosome [*see* below]. In the middle of this face the zigzag axis can be seen pressed into the periderm, and on either side a row of pentagonal meshes, while on the right hand side a row of apertures, consisting of square meshes is shown. The three rows of meshes seen in compressed specimens correspond, hence, to the two rows of one lateral face and one apertural row of meshes. Plate 31, figure 9 is the counterpart of the same specimen. This shows the two rows of skeletal meshes themselves at the right side and at the left side, in consequence of the breaking away of a part of the rhabdosome, one of the lateral rows of the meshes of the opposite side. In the original of plate 31, figure 14 the same three rows of meshes are preserved and also the underlying three rows of the opposite side, so that altogether there were six rows in the walls of the rhabdosome.

Gurley's first figure (445) is according to this explanation a frontal view, with the apertural meshes in the middle, while the last figures (447 and 448) represent lateral views with the apertural meshes showing along the margins. His second figure is a view corresponding to our figures 9 and 11, as indicated by the apertural spines along the margins. Plate 31, figure 12 illustrates a not infrequent case, when four rows of meshes appear. This is due to an oblique splitting of the rhabdosome, thus that the two lateral rows of the upper and under side come to lie side by side.

Our remaining figures serve to show the sicula [pl. 31, fig. 15] and the additional apertural structures [pl. 31, fig. 10]. The sicula is minute (1 mm long), but apparently covered with a continuous periderm, protruding beyond the rhabdosome and furnished with a short virgella [fig. 10]. Plate 31, figure 13 is a reproduction of a beautifully preserved specimen which shows (at sicular end) that the mouth ledges did not lie at the extreme distal end of the thecae, but that the outer or ventral wall of the thecae continued obliquely upward and outward beyond the plane of the meshes for a distance of about one fourth the length of the meshes thereby also giving us an indication of the inclination of the thecae. This outer, rooflike part of the thecae is held at both sides by the mucros proceeding from

the junctions of the parietal and mouth ledges. The thecal walls which within the meshes do not seem to have consisted of any hard parts at all would, according to their apertural parts seen in this specimen, appear to have had the position of those of a Diplograptus. The apertures in this specimen and in plate 31, figure 10 do not occupy the full size of the apertural meshes of the skeleton but appear as rather low transversal openings.

Plate 31, figure 13 illustrates well the gradual thinning out of the continuous periderm in antisicular direction. This observation and the one that young individuals show the skeleton only, lead to the inference that the continuous peridermal layer was a gerontic feature of the individual thecae, for even those which have reached full maturity in size (as in 13) do not yet possess it. The nemacaulus has so far not been observed either within the rhabdosome or as antisicular prolongation. It may have been incorporated in one of the six longitudinal structure lines of the rhabdosome, possibly in one of the zigzag axes in the middle of the lateral faces.

Plate 31, figures 16 and 17 represent reconstructions of this form, without and with continuous periderm respectively.

As regards the systematic position of this form, we do not dispute Hall's and Gurley's view that it is congeneric with Retiograptus tentaculatus, for the reason that the structure of the latter is not sufficiently known to permit a definite diagnosis of the genus, and the conclusion of the congeneric relation of the two species is based mainly on their exterior similarity.

The structure of this Retiograptus agrees with that of the majority of the Retiolitidae in the general structure lines but differs from that of the typical, later genera as Retiolites, Stomatograptus and Gothograptus in the greater regularity of the arrangement of the ledges, the absence of the smaller meshes and the presence of a continuous periderm (or rather greater thickness of the latter). It appears in all these features as a more primitive retiolitid and is obviously more closely related to Glossograptus, and especially to such forms as G. quadrimucronatus which it resembles

not only in the exterior of the rhabdosome, but with which it has also in common the character of the skeleton, as far as this is known in the latter species.

Hall's type came from the Normanskill shale at Normanskill. Gurley's fine material was collected in the same horizon at Stockport, Columbia co., in this State, and I have before me suites of specimens from Schodack Landing and Chatham in Columbia county. The species is nowhere common and frequently found fragmentary. Weller has also observed it in the Normanskill shale of New Jersey and T. S. Hall has figured as Clathrograptus cf. geinitzianus a fragment from Lawson, New South Wales, which may be either conspecific or belong to a closely related species.

RETIOLITES Barrande

The Siluric of North America has thus far afforded but a single diprionidian form. This belongs to the genus Retiolites the last of the graptolites with a double series of thecae. Retiolites is the longest known and most typical of that group of genera (Retiograptus, Stomatograptus, Gothograptus) which combine the extreme reduction of the periderm to little more than a network of conchiolinous fibers with their position at the end of the biserial or diprionidian graptolites.

The significance of this combination in regard to the probable mode of life of these graptolites has been discussed in the first part of this work [Mem. 7, p.518] and the suggestion made that with these forms the tendency to lighten the perisarc evolved by the floating or actively swimming habit of the later graptolites had reached its climax, and as the dominance of some of the species in the middle Siluric indicates, also produced a number of well adapted forms.

That the network, however, was not the only perisarcal layer, can already be surmised from the fine carbonaceous film that covers parts of the compressed specimens [*see* pl. 31, fig. 6]; and the fact that pyritized specimens [*see* pl. 29, fig. 7] are totally smooth on their surface, demonstrates that there was still an outer continuous layer. In fact, Holm has shown on

etched specimens that the stronger reticulate layer is covered internally and externally by delicate continuous membranes.

The internal skeleton has become known by the investigations of Tull-

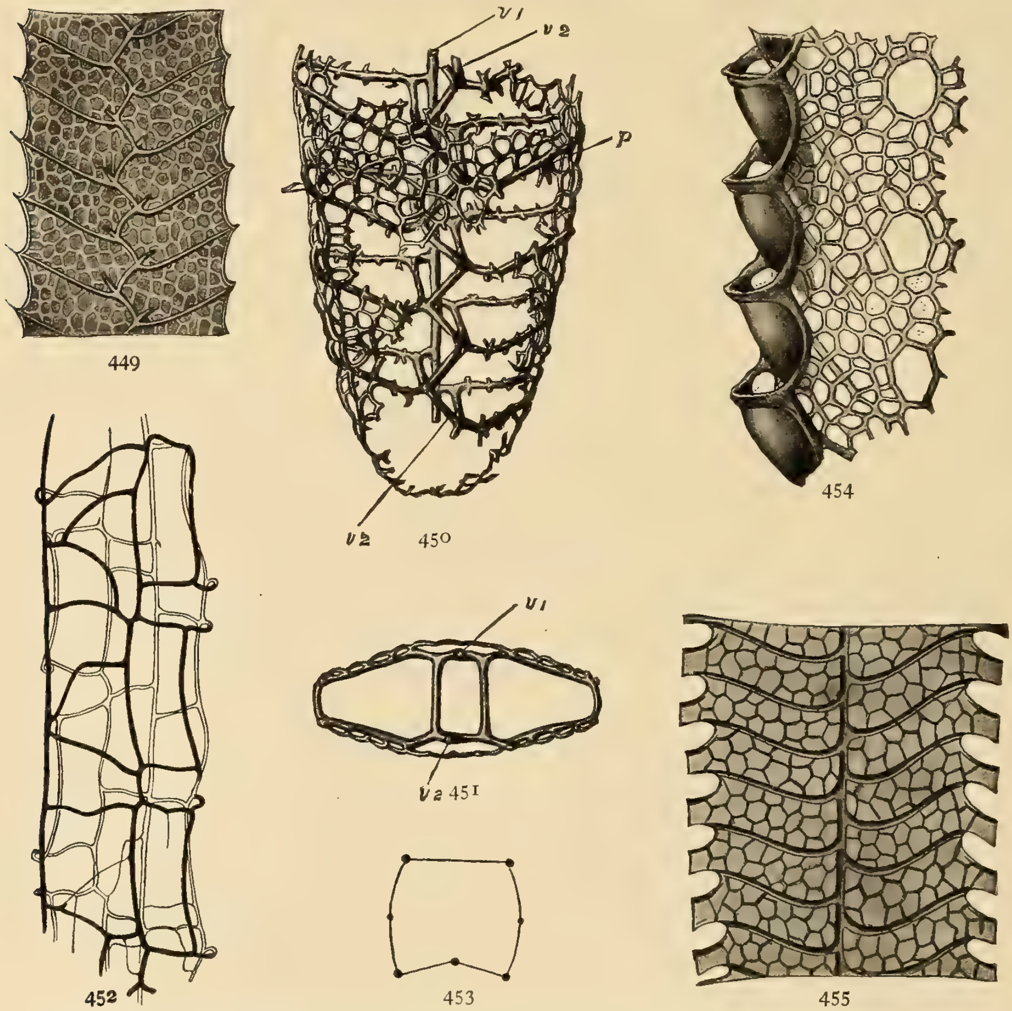

Fig. 449 **Retiolites geinitzianus** var. venosus (Hall). Copy of one of Hall's original figures showing the zigzagged axis and the meshes. Fig. 450, 451 Retiolites geinitzianus Barrande. Fig. 450 Sicular end of an etched specimen; the thick periderm is omitted. Fig. 451 Section of the same, showing as the preceding figure the straight axis (v 1), the zigzagged axis (v 2) and the connecting crossbars. Copies from Holm. Fig. 452, 453 Retiolites nassa Holm. Fig. 452 Portion of rhabdosome near distal extremity showing main strands only. Fig. 453 Diagrammatic section to show position of longitudinal ledges or strands and of "virgula." Copies from Wiman. Fig. 454, 455 Stomatograptus grandis Suess sp. Fig. 454 Reconstruction (after Holm) to show form of thecae. Fig. 455 Flattened specimen. Copies from Perner

berg, Törnquist, Jaekel, Holm and Wiman. It has been shown by these authors that both lateral sides contain solid axes ("virgulas"), one of which

is straight while the other is zigzagged. Both are seen in some of our compressed specimens [*see* pl. 31, fig. 8]. They are held in position by "internal cross-ledges," arranged like the cross-pieces of a ladder [*see* text fig. 450, 451]. From these proceed strong, horizontal, alternating loops, the lateral portions of which (the "parietal ledges") mark the boundaries of the thecae while the distal portions (the "mouth ledges") form the lower rims of the thecal apertures. Strong ledges also bound the lateral margins of the apertures. There do not seem to be any inner partitions of the thecae as in Diplograptus, which Retiolites resembles most in the direction and form of the thecae.

The perisarcal network consists of polygonal meshes. It is fastened to the parietal ledges but adheres only to their middle and distal portions, while it extends independently over the median portion of the lateral faces, covering and hiding the virgula completely in specimens which are not opened by fracture [*see* pl. 31, fig. 7]. In such specimens the parietal ledges will be seen to disappear under the network near the median line.

A sicula has not yet been observed in Retiolites.

The genotype is R. geinitzianus. Of this our American form is but varietally, if at all, different.

Retiolites geinitzianus Barrande var. **venosus** (Hall)

Plate 29, figures 7, 8; plate 31, figures 6-8

Graptolites venosus Hall. Pal. N. Y. 1852. 2:40; pl. 17A, fig. 2a-c
Retiolites venosus Geinitz. Die Graptolithen. 1852. p.58
Retiolites venosus Hall. Pal. N. Y. 1859. 3:518
Retiolites venosus Nicholson. Mon. Brit. Grapt. 1872. p.42, fig. 12
Gladiolites venosus Gurley. Jour. Geol. 1896. 4:79, 308
Retiolites venosus Roemer & Frech. Lethaea Pal. 1897. 1:669, fig. 221
Non Retiolites venosus Spencer.[1] Acad. Sci. Trans. St Louis. 1884. 4:564, 566; pl. 1, fig. 2

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[1] Gurley has in 1896 [*loc. cit.*] pointed out that the specimen figured by Spencer as R. venosus (figure copied by Miller) has no relation to that species and may not be a graptolite. His conclusion is borne out by the material of the National Museum which the writer has in hand.

Non Retiolites venosus Spencer. Mus. Univ. State Mo. Bul. 1884. p.16; pl. 1, fig. 2

Non Retiolites venosus Miller. N. Am. Geol. & Pal. 1889. p.202, fig. 214

Description. Rhabdosome file-shaped, with rounded sicular extremity (.5 mm wide), whence it grows very regularly and gradually in a length of 23 mm to a width of 3 mm to 3.5 mm. From that point its margins remain subparallel. The antisicular extremity has not been observed. The section is depressed elliptic, the lateral faces being gently convex, the frontal faces narrow and straight. The total length attained by the rhabdosome has not been observed; the longest fragment seen measured 34 mm. The sicula has not been observed; the thecae, as indicated by the parietal ledges, number 10 to 14 in 10 mm. They are inclined at an angle of 50°, their apertures are rectangular, and approximately parallel to the axis of the rhabdosome; their lateral margins concave, the upper and lower margins convex and much thickened. The nemacaulus has not been observed.

Position and locality. The species is thus far only known from the Clinton beds in the gorge of the Genesee river below Rochester, N. Y. Hall recorded it from the black layer in the green shales in association with Monogr. clintonensis. Mr H. C. Wardell of this office has also obtained some pyritized specimens from the same shale.

Remarks. The pyritized specimens are entirely smooth and their surface exhibits no trace of the network of fibers, thereby indicating that the exterior perisarcal layer completely covered the meshes of the second layer, leaving only the parietal ledges exposed to a point near the median line of the lateral faces, where they curved gently inward to join one of the "virgulae" [*see* pl. 29, fig. 7, pl. 31, fig. 7].

Upon one of the two pyritized specimens there appear along the median line several low depressions surrounded by low ringwalls, a feature which might suggest that the species was an American representative of the interesting European genus Stomatograptus Tullberg. Holm (Gotlands Graptoliter, 1890) has pointed out that the two genera differ also in

other features, mainly the position of the apertures; Retiolites having its thecal apertures parallel to the main axis and the other having them inclined [*see* text fig. 454]; and that in Retiolites the parietal and mouth ledges are notably thicker than the mesh fibers and in Stomatograptus they are not. In these and other characters our form is a typical Retiolites. Since, moreover, the other and more complete specimen fails to show like circular depressions, it is to be inferred that those of the smaller specimen represent rather an accidental feature of preservation than one of original structure.

I seriously doubt the specific difference of the American form from R. geinitzianus, the genotype of Retiolites; for not only are the two exactly alike in dimensions and habit, but they tally also completely in the number of thecae within 10 mm and in their inclination, as a comparison of my material with Tullberg's [1883] careful drawings and the descriptions of others has clearly shown. Since, moreover, R. venosus is associated with Monograptus clintonensis, which is but little different from M. priodon, and the latter and R. geinitzianus are associated in the middle Siluric of Europe, to the lower part of which our Clinton beds correspond, also the horizon and association of our form are suggestive of its identity with R. geinitzianus.[1]

We have for these reasons, for the present brought R. venosus as a variety under geinitzianus, allowing this distinction to stand less by virtue of differential characters than by that of different geographical distribution. But when the wide areal distribution of R. geinitzianus in Europe (Bohemia, Carinthia, Saxony, Silesia, France, England and Scandinavia) indicating its occurrence in several basins is taken note of, the wide geographical separation of the American and European forms also loses much of its importance.

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[1] Frech has inferred from Hall's figures that it differs from R. geinitzianus in the shorter length of the apertural mucros, but since the latter are but the result of the doubling upon themselves of the mouth ledges and in reality no mucros, this difference can be only one of preservation.

LASIOGRAPTUS Lapworth. 1873

The genus Lasiograptus was erected by Lapworth in 1873 and described as follows:

In the adult polypary of the species of the second type, a slender spine is developed from the outer margin of each theca. At a small but constant distance outside the general boundary of the polypary, this spine subdivides into (or gives off) numerous minute threads, which inosculate with those originating in a similar manner from the spines immediately above and below. These threads form a connected network or braid almost completely surrounding the polypary. Perfect examples are excessively rare, but the specimens belonging to the group can be recognized at once, their margins being apparently furnished with minute tufts of tangled hairs.

As the type of the genus, L. costatus Lapworth (= L. harknessi Nicholson) was named. Two more British species were later made known in L. margaritatus [1876] and L. retusus [1880] by the same author. The former is described as having a continuous series of marginal meshes completely surrounding the polypary, while the latter did not exhibit any exterior meshes in the type specimens and was referred to the genus on account of the form of its thecae.

Hall described in volume 1 in Graptolithus mucronatus a type with similar thecal form and marginal fibers, that was recognized by Lapworth in the Scottish rocks and referred with some doubt to his genus Lasiograptus in 1877. Meanwhile Hall had made his well known observation of subtriangular appendages of the rhabdosomes in "Grapt. whitfieldi" [*see* text fig. 458–61] and described and figured these as reproductive sacs [1865], a view which was generally accepted. When similar lateral processes were found in Diplograptus bimucronatus, it was suggested by Carruthers [in manuscript, *see* Lapworth, Ann. & Mag. Nat. Hist. 1880, p. 188] that this form and the very similar D. mucronatus should be placed into a new genus under the title of Hallograptus. Lasiograptus and Hallograptus were united by Lapworth [*op cit.*] with Retiograptus and Glossograptus under the Lasiograptidae and Lasiograptus defined as including only "those forms in which the 'reproductive sacs' appear to have been protected by a continuous series of marginal meshes" and Hallo-

graptus as having the "gonosome provided with scopulate reproductive processes."

Frech [1897, p.671] in pointing to Lapworth's figures of L. costatus and margaritatus holds that Lasiograptus is a retiolitid, the fibrous bundles forming a part of the periderm of the rhabdosome instead of free appendages, whereby the difference from Retiolites would consist in the fact that the central part of the theca is developed stronger than the apertural part. Lasiograptus is accordingly defined as follows: "Rhabdosome similar as in Retiolites, but the central part of the thecae stronger developed; the fibrous tissues reduced between the latter and the periphery."

The "reproductive sacs" of Grapt. whitfieldi and Lasiogr. bimucronatus are by the same author in another part [p.551] of the above cited work — on account of the finding of gonangia in Diplograptus by the present writer — suggested to have had a protective function (" Deckschuppen ") or to have served as nectophores instead of having been generative organs.

In regard to the American specimens bearing these appendages and identified by Hall with G. whitfieldi, Lapworth has stated [1877, p.134] that they are clearly distinct from that species and most probably belong to a form of Lasiograptus, resembling L. bimucronatus, Nicholson and in the Proceedings and Transactions of the Royal Society of Canada [1886, p.178 ff] has cited L. mucronatus and bimucronatus as synonyms.

It becomes evident from this brief history of the genus, that neither its characters are well known, nor its taxonomic position clearly established, and that the species are not clearly differentiated. I have for these reasons and because of the well known difficulty of reading the structure of rhabdosomes from shale material, brought together as much material as possible of this puzzling group of forms and compared this material with Hall's types. The Normanskill shales at Glenmont near Albany and those of Mt Moreno proved especially rich in remains of Lasiograptus with appendages. The latter, as well as the whole rhabdosomes, exhibit in these collections an astonishing diversity of appearances and modes of preservation,

which are here freely illustrated [*see* pl. 30, 31]. From these specimens we have been able to gather the following facts:

Glossograptus whitfieldi does not possess any marginal filaments, but only two apertural spines, exactly corresponding to those of G. quadrimucronatus. It is most probably, like the latter, a simpler member of the genus Glossograptus. Lapworth's suggestion that Hall's specimens bearing the lateral "reproductive appendages" do not belong to G. whitfieldi is, hence, supported by our material as also by an inspection of Hall's types.

The specimens of Lasiograptus from the Normanskill shale of New York fall easily into two groups, one of slender rhabdosomes with loosely arranged thecae and one of rapidly widening, broad rhabdosomes with closer arrangement of thecae and hence more compact appearance. The former correspond to L. mucronatus Hall, the latter are mostly bimucronate and would hence by this character and the size of the rhabdosomes at once suggest their close relationship or identity with L. bimucronatus Nicholson [*see* below, p. 481]. Hall's appendage-bearing forms belong to the latter group.

In regard to the morphology of Lasiograptus our material leaves no doubt that the organisms grew in synrhabdosomes [*see* pl. 29], at least in L. mucronatus. The latter species has furnished us several compound colonies in the shale from Glenmont, N. Y.; among them one with a well preserved center [*see* pl. 31, fig. 3].

The structure of the rhabdosome of Lasiograptus is evidently very complicated and can be obtained only by conjecture in our shale material.

The great majority of the specimens of both species retain only the thecae and short apertural mucros. The thecae are characterized by the long, horizontal apertural margins [*see* pl. 30, fig. 1, 5, etc.]. The periderm of the thecae is extremely thin and lacks the luster of that of other graptolites, recalling in this feature that of Cryptograptus and Retiolites; and that of L. mucronatus is evidently still much thinner than that of L. bimucronatus.

Along the apertural and ventral margins run distinct fibrous thickenings of the periderm [*see* text fig. 457, 465] which in form and position correspond to the mouth ledges of Glossograptus. In macerated specimens [*see* pl. 30, fig. 2] horizontal ledges are seen to proceed from nodes of the nemacaulus [*see* text fig. 463] and to form by reaching beyond the thecae the long, diverging fibers between which the "reproductive sacs" are enclosed.

The only comparable structure with which we are acquainted are the strengthening bands of Climacograptus retioloides Wiman [*see* text fig. 50, p. 124]. These thickenings of the middle layer of the periderm are described by Wiman [1895, p. 38] as passing horizontally outward along the double longitudinal septum, then turning at right angles and crossing the proximal parts of the thecae until they reach the interthecal walls, when they bend upward under 45° and unite at the bases of the loops on the ventral walls of the thecae. The great similarity in form of these loops to those of the apertural fibers of Lasiograptus is in this connection of especial significance as indicating another structure common to C. retioloides and to Lasiograptus. Wiman's view that this form throws some light upon the Retiolitidae and Frech's that it, on account of its loops, may have led to Lasiograptus, are both supported by the presence of like strengthening bands in the rhabdosomes of Lasiograptus. Moreover, a comparison of Wiman's figure with those of Lasiograptus [as pl. 30, fig. 5] will at once bring out the singular similarity in the shape of the thecae of this Climacograptus and of Lasiograptus. From our observations, here recorded, we infer that the periderm of Lasiograptus was extremely thin and supported by strengthening bands, one of which had the direction above described and another of which surrounded the aperture.[1]

Probably there had also begun the formation of a fine fibrous network in the periderm, corresponding to that of other Retiolitidae, for traces of such have been noticed in several specimens.

We will now turn to the appendages. In the great majority of the

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[1] It is also noted by Wiman that in C. retioloides the margins of the apertures are thickened.

specimens only the bases of the appendages are preserved and appear as mucros, which mostly are flaccid and bent, but sometimes fully as straight and horizontal [*see* pl. 29, fig. 17] as in Glossograptus whitfieldi and thereby may lead to confusion with that species. There are always two mucros below the aperture of each theca. In L. mucronatus these remain so close together [*see* pl. 31, fig. 2] that but rarely they appear double, while in L. bimucronatus [*see* pl. 30, fig. 5] they diverge at once and thereby show their paired character quite distinctly. Nevertheless specimens are frequent [as the original of pl. 29, fig. 12] where one portion is distinctly mucronate and another bimucronate, while in a third the mucros may be so rigid and horizontal that it has the appearance of a G. whitfieldi [pl. 29, fig. 17].

In specimens where more than the stronger bases of the appendages are preserved, very different aspects are possible. In most of them long fibers, often bearing tufts of finer fibers [pl. 30, fig. 6–8; text fig. 459, 462] or in some cases with patches of reticulate tissue [pl. 30, fig. 1] are proceeding more or less horizontally from the rhabdosome. In many others, especially of L. mucronatus, these fibers are more completely preserved [pl. 29, fig. 18; pl. 30, fig. 4]. Each is seen to recurve to the preceding one and to fasten itself to the same, whereby a double festoon originates. This is subparallel with its outer margin to the rhabdosome, the margin mostly consisting of convex segments, but sometimes also being rigidly straight. In a number of specimens of L. mucronatus [*see* pl. 30, fig. 5] the parallel bases of the two fibers of each theca remain connected by a periderm, thereby forming a tonguelike process.[1] This periderm does not end abruptly at the distal end, but fades very gradually thereby indicating that it extended still farther out. Indeed other specimens [*see* pl. 31, fig. 2] retain patches of periderm near the outer margin of the festoon and in others [*see* pl. 30, fig. 8] the triangular peridermal extension can be directly traced between the diverging fibers to near the outer margin, the fibers

[1] This is one of the reasons that L. mucronatus so rarely appears bimucronate in the shale.

here retaining their original recurving direction. Also these triangular extensions become thinner and thinner and finally fade towards the outer margin.

The much discussed "reproductive sacs," figured by Hall [*see* text fig. 458–61], have now exactly the triangular form of these peridermal extensions; they are bounded on both sides by the same diverging fibers and fade at their distal ends exactly as the latter. Since, however, the bounding fibers have lost their connection with the corresponding fibers of the preceding thecae, the triangular extensions have changed their original recurving direction into a horizontal one and appear now as free appendages suggesting vesicles or sacs which have opened distally [*see* pl. 29, fig. 16; pl. 30, fig. 3, 8]. Still, even with the distal ends free, they frequently retain more or less of their original recurving position, as in plate 30, figure 3.

On the base of these observations we consider the "*reproductive sacs*" *of Lasiograptus as flat, horizontal extensions of the periderm of the lower apertural margins of the thecae between the bases of the apertural loops.*

There are other observations supporting this view. In the best preserved appendages a system of cross-fibers can be seen to connect the bounding main fibers [*see* pl. 30, fig. 8] and in others these are seen to be again connected by finer fibers, the whole forming a fine meshwork. In others [*see* especially pl. 30, fig. 1] the bases of the main fibers are connected by a system of fine longitudinal fibers running parallel to the axis of the rhabdosome, and these again form together with transverse fibers a meshwork, that must have screened the vertical sides of the spaces formed by the horizontal apertural extensions described above. The result were prolongations of the thecae, amounting to twice and more of their length as given by the continuous periderm. I have tried to illustrate the structure of these extended thecae as I derive it from my material, in diagram plate 31, figure 5. The similarity between this thecal structure and that of the later Stomatograptus is very pronounced. The final aperture lay between the recurving parts of the two main fibers above the point

where now the periderm of the triangular appendages is fading out (at *a* in diagram).

On account of the very different structure of the thecae proper and of their distal parts, we believe that the latter do not simply represent a stronger reduction of the periderm of the distal parts of the original thecae but rather a secondary development. The origin of the latter has probably to be sought, as mentioned before, in the apertural loops of Climacograptus retioloides. This latter view seems to be well supported by further observations regarding the appendages which have not yet been recorded here. One of these is that the appendages are much greater in size near the older (sicular) extremity of the rhabdosome and absent or hardly developed at the other end [*see* Hall's type refigured pl. 29, fig. 16]. In other words they lag in their growth far behind that of the thecae. In the last mentioned figure it will be seen that while the thecae at the antisicular end are almost as large as those at the sicular end, the thecal appendages are only indicated there as slight swellings (at *a*), but grow distinctly in size towards the other end. Besides, they are there distinctly thicker in texture than the older and larger appendages and fully bounded by a fiber at their rounded distal ends. All this can not fail to suggest growing saclike appendages as it did to Hall. But if we assume that these distal loops of the thecae are but of later secondary development, it may well be expected that they also lagged behind in time of appearance or in the ontogenetic development of the thecae and of the rhabdosome, as they actually would appear to do in the specimens figured.[1]

Another point bearing on the connection of Lasiograptus and Climacogr. retioloides is the like form of their thecae. A comparison of the figure of the latter species, copied here from Wiman [fig. 50] and of figure 456 will show at once that the outlines of the thecae of both are alike and differing from those of other retiolitids and diplograptids, in that the

[1] The specimens are slightly twisted, the sicular moiety being obliquely compressed and the other showing the frontal or ventral aspect, but this could not possibly affect the preservation of the appendages to the degree here shown.

ventral margin is in both raised to the base of the loop and the apertural margin horizontal to receding; both combined producing a bluntly acute distal extremity of the theca which is very characteristic of Lasiograptus.

We have observed but one axis in our material, which corresponds to the nemacaulus.

Lasiograptus mucronatus (Hall)

Plate 29, figures 9, 10, 11; plate 30, figures 1–5; plate 31, figures 1–3

Graptolithus mucronatus Hall. Pal. N. Y. 1847. 1:268; pl. 73, fig. 1a–d

? Diplograptus mucronatus Geinitz. Die Graptolithen. 1852. p.23

Diplograptus mucronatus Carruthers. Geol. Sur. Mem. 1866. 3:330; pl. 11A, fig. 6; pl. 12, fig. 1

Diplograptus mucronatus Nicholson. Geol. Mag. 1867. 4:113; pl. 7, fig. 5, 5a

Diplograptus mucronatus Carruthers. Geol. Mag. 1868. 5:13; pl. 5, fig. 2

Diplograptus mucronatus Nicholson. Geol. Soc. Quar. Jour. 1868. 24:139

? Diplograpsus mucronatus M'Coy. Pal. Victoria. Prodr. Dec. 1. 1874. p.10; pl. 1, fig. 5

Non Diplograptus mucronatus Etheridge jr. Ann. & Mag. Nat. Hist. 1874. 14:5; pl. 3, fig. 14–17

? Diplograptus (Lasiograptus) mucronatus Lapworth. Belfast Nat. Field Club. An. Rep't & Proc. v. 1, apx. 1877. p.134; pl. 6, fig. 22

Diplograptus mucronatus Walcott. Alb. Inst. Trans. v. 10. 1883. (Advance sheets. 1879. p. 34)

Diplograptus mucronatus Ami. Can. Geol. Sur. Rep't. Ser. 2. 1889. v. 3, pt 2, p.117K

Lasiograptus mucronatus Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:178f

Diplograptus mucronatus Walcott. Geol. Soc. Am. Bul. 1890. 1:339

Lasiograptus mucronatus Gurley. Geol. Sur. Ark. An. Rep't. 1892. 3:413

Lasiograptus mucronatus Gurley. Jour. Geol. 1896. 4:299

Lasiograptus mucronatus Rüedemann. N. Y. State Mus. Bul. 42. 1901. p.544

Diplograptus mucronatus Clark. Geol. Mag. Ser. 4. 1902. 9:498

Lasiograptus mucronatus Weller. Geol. Sur. N. J. Pal. 1902. 3:52

Lasiograptus mucronatus Dale. U. S. Geol. Sur. Bul. 242. 1904. p.33

Diagnosis. Synrhabdosome apparently composed of small number of rhabdosomes; 8 being greatest number of rhabdosomes and 15 that of bases of nemacauli observed. Rhabdosomes slender, of lax appearance, with very thin periderm; attaining a length of 35+ mm; 1 mm wide at the sicular extremity and growing within the space of 8 mm to full width, which as a rule is about 2 mm, but may rise to 2.5 mm and is maintained to the truncate antisicular extremity. Sicular extremity rounded; sicula small, apparently not longer than 1.2 mm; furnished with two filiform apertural processes, one of which (the virgella) lies in the direction of the axis. Thecae numbering 8 to 10 in 10 mm (20–26 in 1 inch), slender, overlapping not more than one half, inclined at low angle (20–30°), with straight to concave outer margin which in the last distal third is extended outward horizontally and produced into the main fibers of the outer meshwork. The apertural margin is horizontal or even receding, often concave; the apertural excavation long triangular, one third the transverse width of the rhabdosome and half the length of the theca. The outer meshwork is very delicate, hence lost in the great majority of specimens, where but the thicker bases of the main fibers are

456

457

Fig. 456–57 Lasiograptus mucronatus (Hall). Fig. 456 Typical appearance of rhabdosome. Fig. 457 Portion of rhabdosome showing character of sicular end and traces of ledges. x 5

preserved, which produce the mucronate appearance. The meshes extend on either side of the rhabdosome to a distance equal to the width of the rhabdosome. The nemacaulus is extremely thin, quite flexible and rarely more than half the length of the rhabdosome.

Position and localities. L. mucronatus is in New York one of the common graptolites of the Normanskill shale and found in all the principal localities. Ami and Lapworth have recorded it from several outcrops of the same horizon in the province of Quebec and Gurley has also found it in beds belonging to his Upper Dicellograptus zone at Magog, Canada. The same author cites it among the fossils of the Lower Dicellograptus zone of Arkansas. In Great Britain, Carruthers, Nicholson and Lapworth have frequently cited it and Lapworth's tables of 1880 showing the range of the graptolites in Great Britain contain it as a Glenkiln species. The form from the shales at Newham, near Lancefield, in Victoria, which has been identified by Etheridge with our species is associated with species of the Deepkill zones or Point Levis shales and represents a Retiograptus, closely related to R. tentaculatus Hall. Neither can the Australian form, identified by McCoy with this species, have been properly placed.

Remarks. We have already shown that the mucros are always double, and that their simple appearance in the compressed material is due to their close union by the inclosed peridermal extension.

Lasiograptus bimucronatus (Nicholson)

Plate 29, figures 12–18; plate 30, figures 6–8; plate 31, figure 4

Graptolithus sp. Hall. Pal. N. Y. 1859. 3:507, fig. 1–3

Graptolithus whitfieldi Hall. Can. Org. Rem. Dec. 2. 1865. pl. B, fig. 6–11

Diplograptus bimucronatus Nicholson. Ann. & Mag. Nat. Hist. 1869. 4:236; pl. 11, fig. 12

Hallograptus bimucronatus Lapworth. Cat. West. Scott. Foss. 1876. p.7; pl. 2, fig. 58

Diplograptus (Hallograptus) bimucronatus Lapworth. Belfast Field Club. An. Rep't & Proc. Ser. 2. apx. 1877. pt 4, p. 134; pl. 6, fig. 23

Lasiograptus bimucronatus Tullberg. Sver. Geol. Und. Ser. C, no. 50. 1882. p. 20

Lasiograptus mucronatus Lapworth. Roy. Soc. Can. Proc. & Trans. 1887. 4:178 f

Lasiograptus bimucronatus Gurley. Jour. Geol. 1896. 4:299

Hallograptus (Lasiograptus) bimucronatus Roemer & Frech. Leth. Pal. 1897. 1:672, fig. 224

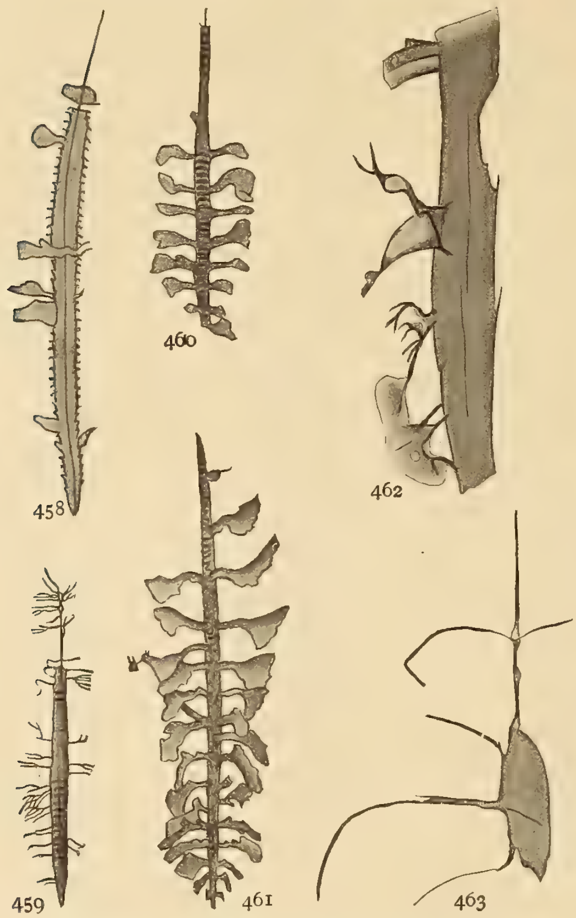

Fig. 458–63 Lasiograptus bimucronatus (Nicholson.) Fig. 458–61 Copies of Hall's figures (originally referred to Graptolithus whitfieldi). Fig. 462 Portion of specimen showing the appendages in a much macerated (the usual) condition. Fig. 463 Young rhabdosome showing at the upper end the fixation of the ledges to the nemacaulus. The last two figures, x 5

Lasiograptus bimucronatus Roemer & Frech. Lethaea Pal. 1897. 1:672, fig. 224

Diplograptus bimucronatus Clark. Geol. Mag. Ser. 4. 1902. 9:499

Besides the slender form with loosely arranged thecae just described, there occurs in some outcrops of the Normanskill shale, notably those at Glenmont and Mt Moreno, still another coarser form, which differs in greater final width of rhabdosome, closer arrangement of thecae and the mucros, which on account of their earlier divergence appear nearly always paired in the shale material. The periderm is thicker, and the mucros are stronger, frequently straight and of the appearance of the horizontal spines of Glossograptus quadrimucronatus. It agrees in its characters and dimensions with Nicholson's original description which is the only one extant.

Description. Synrhabdosome not observed. Rhabdosome medium sized, attaining a length of 45 mm or more, with rounded sicular extremity which is 1 mm wide; attaining its mature width of 3+ mm very gradually, in a distance of about 15 mm. Last moiety of rhabdosome with parallel margins. Antisicular extremity truncate. Sicula not observed. Thecae numbering 10 to 12 in 10 mm (25–30 in 1 inch), inclined at an angle of 30°, overlapping one half or a little more. Form of thecae as in L. mucronatus. Outer meshwork also as in latter species, but coarser. Nemacaulus very thin and short.

Position and localities. In the Normanskill shale at Kenwood and Glenmont near Albany, N. Y. and on Mt Moreno near Hudson. In Great Britain the form is recorded from the Glenkiln shales of Scotland, from Wales and Ireland and Tullberg cites it among the graptolites of the zone with Coenograptus gracilis in Scania.

Remarks. The differences between L. mucronatus and bimucronatus are largely such of relative dimensions. The writer has therefore been long in doubt as to the propriety of distinguishing the two forms; the fact, however, that they rarely associate in the same layer and that the larger and coarser form has the thecae arranged more closely instead of more loosely, as one should expect, gives to the latter a so much more compact appearance that confusion between the two is little to be feared. The firmer texture of the periderm in this species finds its expression also in the more frequent preservation of the extrathecal meshwork and of the peridermal expansions. It was in examples of this species then referred to Graptolithus whitfieldi that Hall observed the "reproductive sacs."

Lasiograptus bimucronatus (Nicholson) mut. **timidus** nov.

Plate 29, figures 19, 20

The Utica shale of New York, that of Cincinnati and the Maquoketa shale near Granger contain a peculiar small spinose form which obviously is very rare and has all the appearance of a gerontic mutation of one of the spinose species of the Trenton shales. Its principal characters are its com-

pact form, due to its small length (mostly but 6–7 mm) and relatively great width (2 mm when obliquely compressed), the close arrangement of its thecae (14 in 10 mm) and the length of the horizontal, rigid spines (1.5–2 mm). From the rigidity and the direction of the spines a reference to Glossograptus whitfieldi would appear reasonable, and the Cincinnati specimens have indeed been referred to that species by Ulrich in 1880. The Maquoketa specimens, however, exhibit the peculiar, very narrow or very broad aspects — according to the face exhibited — of the rhabdosome and the spatulate appendages of the spines characteristic of Lasiograptus [*see* fig. 465], and show thereby that we have before us a late dwarfed mutation of L. bimucronatus. The small size, relatively great width, rigidity and length of the spines and probably also the scarcity of the forms are all characters pointing to the same phylogerontic condition of this mutation.

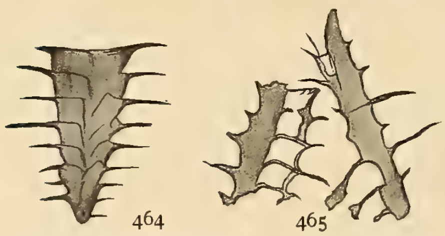
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Fig. 464–65 Lasiograptus bimucronatus mut. timidus nov. Fig. 464 Specimen from Utica shale at Flat creek, Mohawk, N. Y. Fig. 465 Specimens from Granger, Minn. x 5

The Cincinnati specimens are less shortened than the others and have still more widely arranged thecae (8–9 in 10 mm); they would appear to represent a somewhat less reduced mutation than the others.

Position and localities. I have before me material of this mutation from the higher Utica shales at Flat creek near Mohawk village, N. Y. (in association with Climacogr. putillus); from the Utica shale at Holland Patent (with Climacogr. typicalis and Leptobolus insignis); from the true Utica shale at Cincinnati [Ulrich collection] and from the Maquoketa shale (Diplograptus bed Sardeson) at Granger, Minn. [Sardeson collection].

ADDENDA

Note on Dawsonia

The history of this genus of somewhat doubtful standing and the description of two species from the Deepkill shales have been given in part 1 of the *Graptolites of New York.*

In the present paper a species is described as Azygograptus ? simplex which formerly had been identified by the writer with Dawsonia campanulata Nicholson. The subject of this note consists of small appleseed-shaped carbonaceous bodies [*see* fig. 467, 468] which occur in a thin band of the Normanskill shale at Schuylerville, Saratoga co. They are in shape and size almost identical with D. acuminata Nicholson; but belonging to a younger horizon (D. acuminata is from the Beekmantown shale at Point Levis), they could not well be identified with the latter. They begin with a rather sharply pointed proximal spine or radicle, which is attached to the narrower end of a small oval body. The latter is broadly rounded at its distal extremity. The length of the bodies is about 3 mm in the majority, 1 mm of which is taken up by the spine. Their substance is carbonaceous, but lacks all growth lines and is notably thinner than that of the graptolites and also lacks the gloss of the latter. They are not associated with graptolites but with branching carbonaceous bodies [*see* fig. 468] which have the form of sponges and may be remains of either horny or calcareous sponges, the calcareous portion of whose skeletons has been dissolved.

466

467

468

Fig. 466 Dawsonia acuminata Nicholson. Copy from Nicholson. Fig. 467, 468 Graptospongia pusilla gen. nov. et spec. nov.

Since bodies apparently connecting the "Dawsoniae" with the larger multitubular organisms occur in the same band [*see* fig. 467] the inference that these "Dawsoniae" are young growth stages of the latter suggests itself, though it must be remarked that the material is not complete enough to be conclusive. For the sake of reference we propose to name the mature form Graptospongia pusilla.

Note on Caryocaris wrightii Salter

The writer has identified a small fossil from the lowest Deepkill zone with Caryocaris cf. curvilatus Gurley and described it in the supplement of Memoir 7, stating that though Dr Gurley has referred these bodies to the graptolites [1896, p.85], his views are greatly at variance with those of the authors of the *Monograph of the British Phyllopods.*

In the meanwhile an opportunity has presented itself of studying the excellently preserved material of C. wrightii and curvilatus from the Piñon range of Nevada, on which Dr Gurley's conception of the graptolite nature of Caryocaris is based. Noting that this allows an entirely

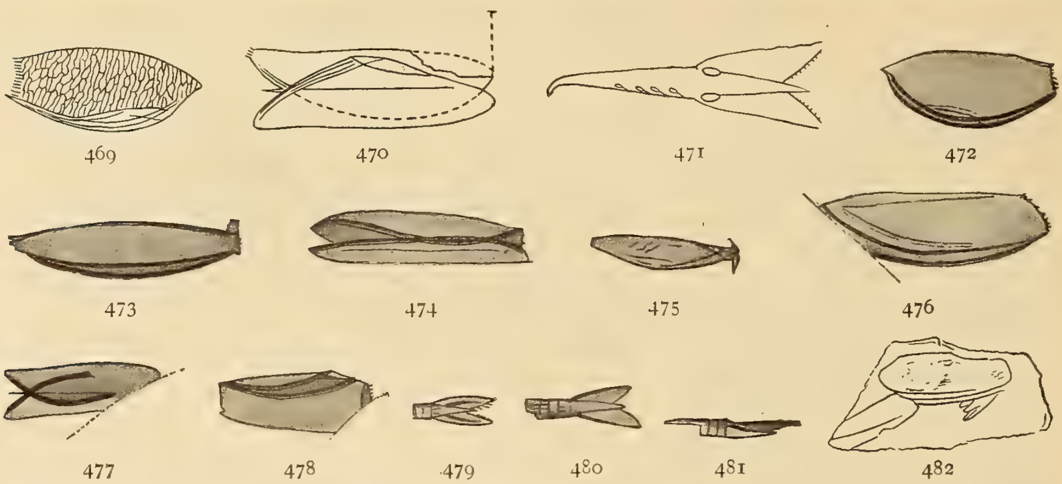

Fig. 469–82 Caryocaris wrightii Salter. Fig. 469–70 Copies of Gurley's figures of Caryocaris curvilatus. (1896, pl. 4, fig. 3; pl. 5, fig. 3). Fig. 471 Copy of one of Gurley's figures of Caryocaris wrightii. Fig. 472–78 Various aspects of carapaces. Fig. 479–81 Abdomina. Fig. 482 Copy of figure by Jones and Woodward, showing carapace and tail. Fig. 472–81 are drawn in natural size. The originals are in the National Museum

different interpretation, the writer desires to improve this opportunity of presenting his view.

Dr Gurley has distinguished two different groups of bodies, viz, (1) the pod-shaped bodies described by Salter and the Monographers of the British Phyllopods as the carapace of Caryocaris [*see* text fig. 469, 470] and (2) "winged bodies." The latter [*see* text fig. 471] are considered as the complete bodies of Caryocaris, consisting of "two symmetrical paired lateral appendages attached to the distal end of a single median proximal portion on which thecae could perhaps be traced." The bodies of the first group

are held to be nothing but the detached lateral appendages of another species (C. curvilatus).

In looking over the suite from Piñon range with this conception of Caryocaris in mind, one can not help noticing the disproportion in size between the supposed complete bodies and the detached appendages. As the drawings in natural size, given here [text fig. 472–81] show, the winged bodies are throughout of much smaller size than the mostly quite stately "appendages"; their proportion is about what one would expect to be that of the abdomen to the carapace. In a careful scrutiny of the winged bodies the latter turned out to consist of an abdomen showing, when complete, three somites and three caudal spines [479–81].

Jones and Woodward have figured a specimen received from Malaise, in which a trifid tail extends from below the narrow extremity of the carapace [*see* text fig. 482] showing the cercopods. Of these it is stated:

> They are not wholly exposed, but evidently comprise three lancet-shaped, flat, thin, bladelike members, one of which, apparently larger than the others, as far as they are exposed, may be the style or chief cercopod. We do not know any set of style and stylets exactly corresponding to these.

A comparison of our figures of the cercopods with that given by Jones and Woodward shows the great similarity in shape of the two broad and flat lateral cercopods while the style or telson in our form is relatively shorter and more acute. The cercopods possess a stronger axis than the style. This mostly appears along the outer margin and probably corresponds to the spinelike caudal appendages observed in most phyllopods, bearing here a bladelike extension.[1] Cases of actual connection of the abdomen with

[1] Jones and Woodward cite several forms with similar caudal appendages, among the Elymocarids. The caudal appendages of Elymocaris siliqua from the Chemung group in Pennsylvania bear indeed a close resemblance to those of this Caryocaris. The telson is described by Dr Clarke [Pal. N. Y. 7: 183] as "short and stout and bearing a conspicuous median ridge" and the cercopods as "flat, comparatively narrow and longer than the telson, and (are) minutely crenulated along their inner edges for the attachment of setae." The setae of the cercopods, observed in Elymocaris and other phyllocarids are also distinct on the inner margins of the caudal appendages of C. wrightii [*see* fig. 479], and already brought out in Gurley's figure [*see* text fig. 471].

the carapace are very rare in the Piñon range material, only one specimen having been observed [reproduced in text fig. 475].

That the larger bodies considered by Gurley as the detached lateral appendages of the graptolite are true carapaces, is abundantly shown by their outline[1] and by numerous specimens, compressed in dorso-ventral or oblique direction. In these latter states of preservation the composition of the carapace of two equal sides, folded upon each other and united along the dorsal line (either by coalescence or by hinge) and the gaping of the ventral part can be distinctly seen [*see* fig. 472 and 474].

The exclusion of Caryocaris from the graptolites does not directly affect the position of Dawsonia among the latter.

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[1] The normal outline of the carapace is seen in the specimen reproduced in text figure 472. The dorsal margin makes a somewhat abrupt turn near both the anterior and posterior extremities and the carapace may have been gaping there a little [*see also* anterior extremity of text fig. 473]. The anterior extremity possessed two acute mucros [*see* text fig. 472, 473], suggestive of Elymocaris capsella and Tropidocaris bicarinata and of other phyllocarids. The ventral margins show well the thickening by raised rims, mentioned by Jones and Woodward. The posterior margin is straight, truncate and vertical, without any trace of thickened rim, but provided with a fringe which is due to the "plaiting" or imperfect cleavage of the shale. The dorsal margin in the laterally compressed carapaces shows no trace of thickening or of a hinge or suture, but in obliquely or dorso-ventrally compressed specimens [*see* text fig. 474, 477] a distinct, straight line of the nature of a break appears in the exact location of the dorsal (median) line of the carapace, running the greater length of the latter and suggesting a hinge line. On Gurley's type of C. curvilatus [text fig. 477] this line is more prominent than any other and ends anteriorly in a lancet-shaped process protruding from the carapace and corresponding in form and position to the rostrum observed in the later phyllocarids. Altogether one can not, in noting the additional features of the carapace here enumerated, fail to be impressed with the greater similarity of this crustacean rather to such Devonian genera as Elymocaris and Tropidocaris than to the older Hymenocaris.

EXPLANATION OF PLATES

PLATE 1

Genus CALLOGRAPTUS Hall

Callograptus compactus (Walcott)

Page 146

1 Rhabdosome with adhesion disk (topotype)
Utica shale, Holland Patent, Oneida co., N. Y.

Genus DESMOGRAPTUS Hopkinson

See plates 4, 5

Desmograptus tenuiramosus sp. nov.

Page 177

2 Type specimen (holotype)
Normanskill shale, Glenmont, Albany co., N. Y.

Genus DICTYONEMA Hall

See plates 2-5

Dictyonema scalariforme Foerste

Page 153

3 Fragment of rhabdosome
Ferruginous Clinton shale, Clinton, N. Y.

Dictyonema spiniferum sp. nov.

Page 151

4 Fragment of rhabdosome (holotype)
Normanskill shale, Glenmont, Albany co., N. Y.

Dictyonema gracile Hall

Page 157

5 Rhabdosome retaining proximal portion (homoeotype)
Rochester shale, Middleport, N. Y.

GRAPTOLITES

R. R. del.

Genus ODONTOCAULIS Lapworth

Odontocaulis hepaticus sp. nov.

Page 174

6 Rhabdosome with proximal portion (cotype)

7 Frond of another specimen (cotype)

Normanskill shale, Glenmont, Albany co., N. Y.

Genus PTILOGRAPTUS Hall

Ptilograptus poctai sp. nov.

Page 148

8 Fragment of rhabdosome (holotype)

Normanskill shale, Glenmont, Albany co., N. Y.

Ptilograptus hartnageli sp. nov.

Page 149

9 Single specimen observed (holotype)

Clinton shale, Stirling station, Cayuga co., N. Y.

All figures are drawn in natural size and all originals are in the New York State Museum.

PLATE 2

Genus DICTYONEMA Hall

See plates 1, 3-5

Dictyonema subretiforme (Spencer)

Page 162

1 Large rhabdosome expanded

2 A smaller rhabdosome compressed laterally and showing the proximal parts

Rochester shale, Middleport, N. Y.

Dictyonema polymorphum Gurley

See plate 3, figures 4-6

Page 158

3 Large rhabdosome (homoeotype)

Rochester shale, Middleport, N. Y.

Genus INOCAULIS Hall

See plate 7

Inocaulis plumulosus Hall

See plate 7, figures 1, 2

Page 188

4 Fragment of rhabdosome showing distal portions of branches with tubular branchlets and impressions of their apertures on the cast of the branches

Niagara limestone, Hamilton, Ontario

Genus CYCLOGRAPTUS Spencer

Cyclograptus rotadentatus Spencer

Page 184

5 Large specimen from the Clinton group, Clinton, N. Y. (homoeotype)

All figures are drawn in natural size; the originals of figures 1, 2, 3, 5 are in the New York State Museum; that of figure 4 is in the National Museum.

R. R. del.

PLATE 3

Genus DICTYONEMA Hall

See plates 1, 2, 4, 5

Dictyonema retiforme Hall

Page 155

1 Fragment of rhabdosome with typical structure (homoeotype)
Rochester shale, Lockport, N. Y.

Dictyonema blairi Gurley

Page 171

2 Fragment of rhabdosome (cotype)
Choteau limestone, Sedalia, Mo.

Dictyonema leroyense Gurley

Page 167

3 Type specimen (holotype) showing proximal parts
Onondaga limestone, Leroy, N. Y.

Dictyonema polymorphum Gurley

See plate 2, figure 3

Page 158

4 Distal portion of rhabdosome (paratype)
5 Rhabdosome with central portion. Gurley's type (holotype)
6 Rhabdosome retaining adhesion disk (cotype)

Genus PALAEODICTYOTA Whitfield

See plate 6

Palaeodictyota bella (Hall & Whitfield)

Page 203

7 Type specimen redrawn from photograph (holotype)

All figures are drawn in natural size; the originals of figures 1 and 6 are in the New York State Museum, the others in the National Museum with the exception of that of figure 7 which is in the Ohio state collection.

GRAPTOLITES

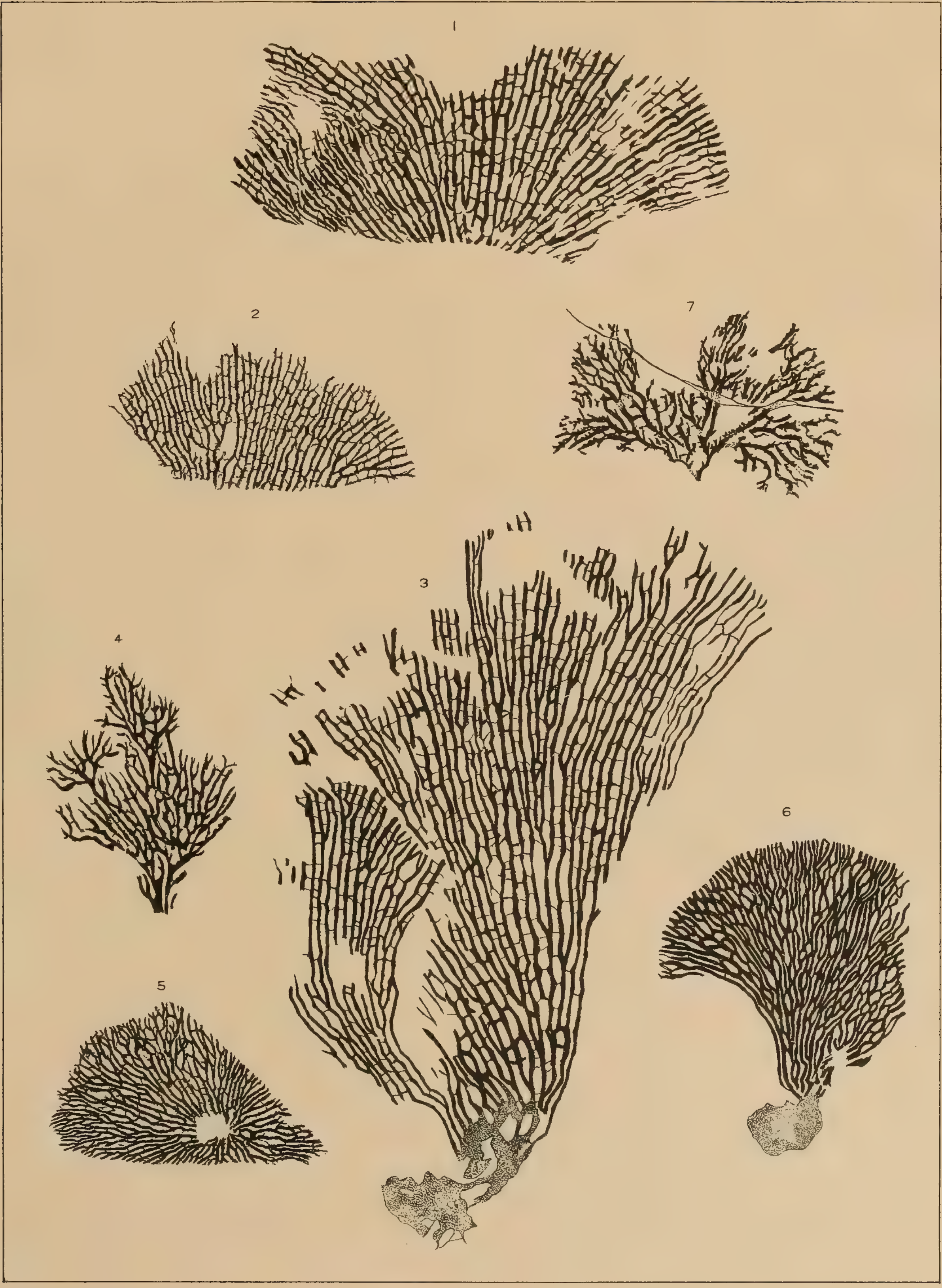

PLATE 4

Genus DESMOGRAPTUS Hopkinson

See plates 1, 5

Desmograptus cadens (Hall)

Page 180

1 Type specimen (holotype ?)

Hamilton shale, Moscow, N. Y.

Genus DICTYONEMA Hall

See plates 1–3, 5

Dictyonema areyi Gurley

Page 164

2 Type specimen (cotype)

Rochester shale, Rochester, N. Y.

Dictyonema perradiatum Gurley

Page 168

3 Type specimen (holotype)

Onondaga limestone, Leroy, N. Y.

Dictyonema hamiltoniae Hall

Page 169

4 A labeled specimen of the Hall collection (cotype ?)

Hamilton shale, Moscow, N. Y.

All figures are drawn in natural size; the originals of figures 1 and 4 are in the American Museum of Natural History; that of figure 2 is in the collection of Prof. A. L. Arey, Brooklyn, N. Y. and that of figure 3 is in the National Museum.

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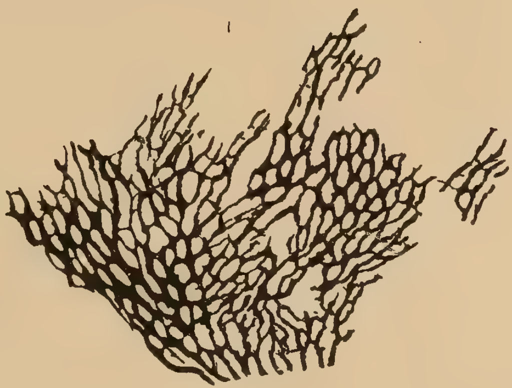

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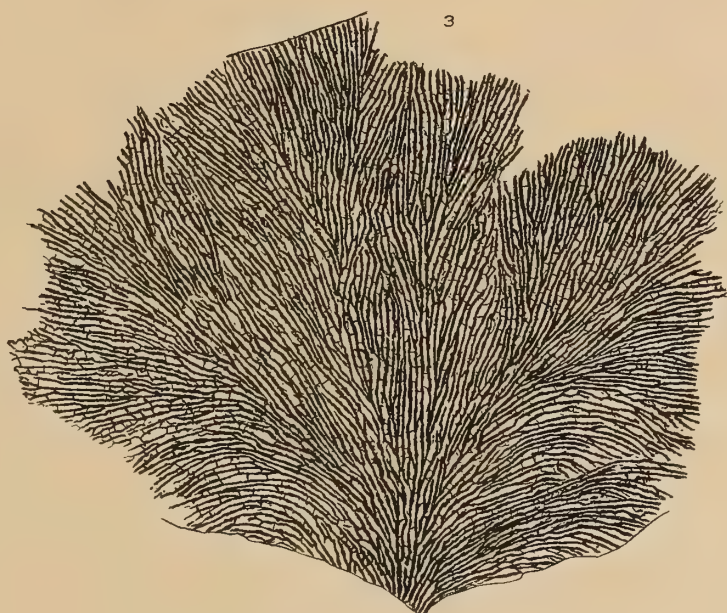

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PLATE 5

Genus DESMOGRAPTUS Hopkinson

See plates 1, 4

Desmograptus becraftensis sp. nov.

Page 179

1 Type specimen (cotype)

New Scotland beds, Becraft Mt near Hudson, N. Y.

Desmograptus vandelooi sp. nov.

Page 181

2 Type specimen (holotype)

Hamilton shale, Hemlock creek, Ontario co., N. Y.

Genus DICTYONEMA Hall

See plates 1–4

Dictyonema crassum Girty

Page 165

3 Most complete rhabdosome observed

New Scotland limestone, Catskill, N. Y.

4 Type specimen (cotype)

New Scotland limestone, Clarksville, N. Y.

Dictyonema megadictyon Gurley

Page 168

5 Type specimen (holotype)

Onondaga limestone, Leroy, N. Y.

Genus PTIOGRAPTUS nov.

Ptiograptus percorrugatus sp. nov.

Page 176

6 Type specimen (holotype)

Middle Devonic (Waterlime), Louisville, Ky.

All figures are drawn in natural size. The originals of figures 1–3 and 6 are in the New York State Museum; that of figure 4 is in Yale University Museum and that of figure 5 in the National Museum.

R. R. del.

PLATE 6

Genus ACANTHOGRAPTUS Spencer

See plate 7

Acanthograptus walkeri (Spencer)

See plate 7, figure 4

Page 194

1, 2 Two specimens from the Rochester shale at Middleport, N. Y.

Acanthograptus granti Spencer

See plate 7, figure 3

3 A nearly perfect rhabdosome, introduced here for illustration of the genus

Niagaran shale, Hamilton, Ontario.

Genus PALAEODICTYOTA Whitfield

See plate 3

Palaeodictyota anastomotica (Ringueberg)

Page 200

4 Large typical rhabdosome from the Rochester shale at Middleport, N. Y.

Palaeodictyota clintonensis sp. nov.

See plate 7, figures 5, 6; plate 8, figure 3

Page 203

5 Fragment of proximal portion (cotype)

Clinton shale, Clinton, N. Y.

Palaeodictyota bella (Hall and Whitfield) mut. **recta** nov.

See plate 7. figure 6

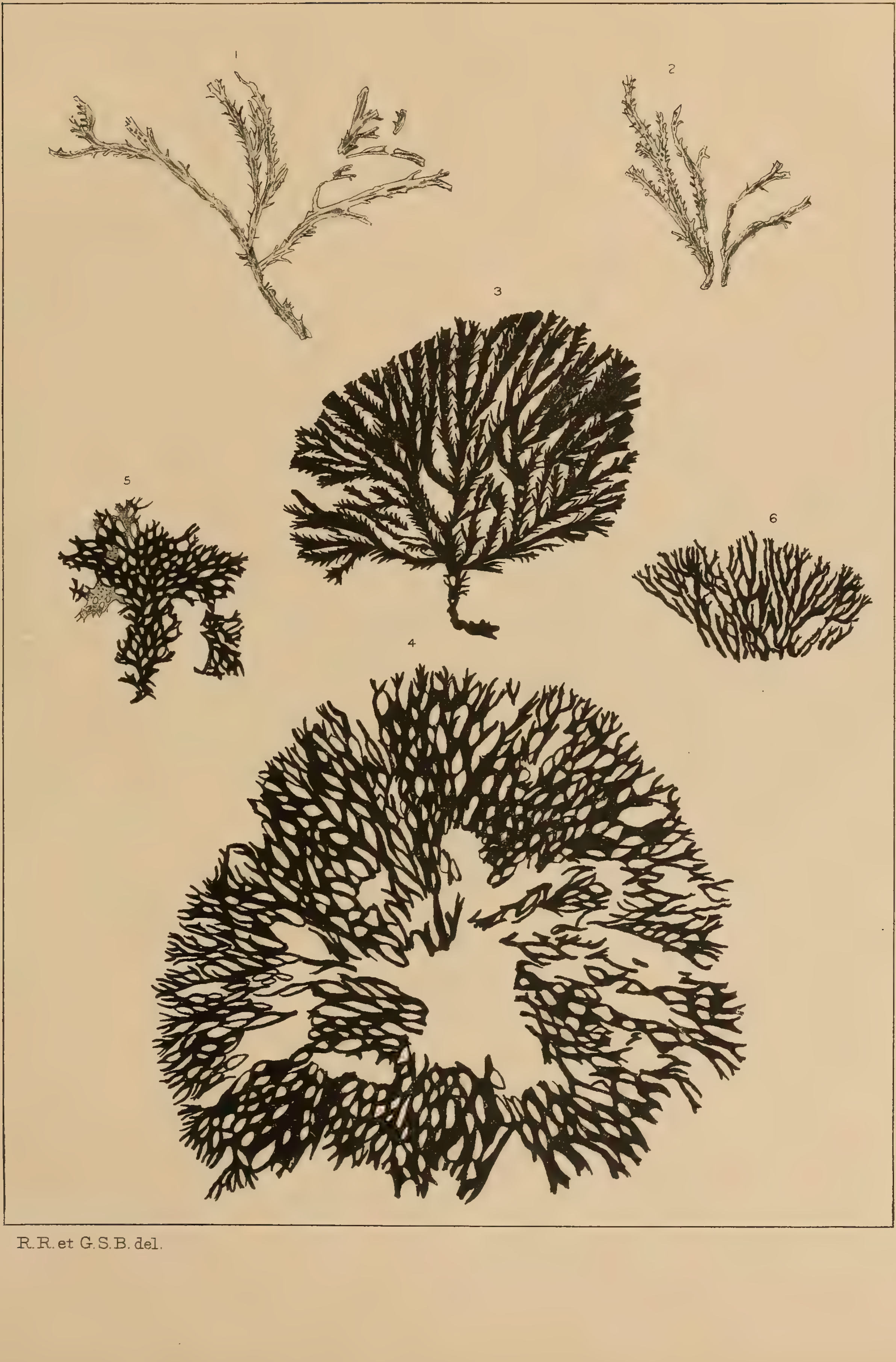
Page 204

6 Type specimen (holotype)

Clinton shale, Clinton, N. Y.

All figures are drawn in natural size. The originals are in the New York State Museum.

GRAPTOLITES



R. R. et G. S. B. del.

PLATE 7

Genus INOCAULIS Hall

See plate 2

Inocaulis plumulosus Hall

See plate 2, figure 4
Page 188

1 Enlargement (x 5) of portion of branch to show the form and composite character of the branchlets (by the apertures in one of them on the right hand side). Periderm not shaded in

2 Enlargement (x 5) of a terminal portion of a branch to show the form of the branchlets

Niagaran limestone, Hamilton, Ontario.

Genus ACANTHOGRAPTUS Spencer

See plate 6

Acanthograptus granti Spencer

See plate 6, figure 3

3 Enlargement (x 5) of distal portion of rhabdosome, introduced for comparison with Inocaulis and Palaeodictyota

Niagaran limestone, Hamilton, Ontario.

Acanthograptus walkeri (Spencer)

See plate 6, figures 1, 2
Page 194

4 Enlargement (x 5) of fragment of branch to show the composite character of the branchlets, indicated by the apertures of thecae

Niagaran limestone, Hamilton, Ontario.

Genus PALAEODICTYOTA Whitfield

See plate 6

Palaeodictyota clintonensis sp. nov.

See plate 6, figure 5; plate 8, figure 3
Page 203

5 Enlargement (x 5) of portion of rhabdosome showing the anastomosis of the branches, and where the periderm is broken away (lighter-shaded parts) the apertures of thecae

Clinton shale, Clinton, N. Y.

GRAPTOLITES

R. R. et G. S. B. del.

Palaeodictyota bella (Hall and Whitfield) mut. **recta** nov.

See plate 6, figure 6

Page 204

6 Enlargement (x 5) of distal portion of rhabdosome to show free terminal thecae

Clinton shale, Clinton, N. Y.

The originals of figures 1, 2, 4 are in the National Museum, the remainder in the New York State Museum.

PLATE 8

Genus CACTOGRAPTUS nov.

Cactograptus crassus sp. nov.

Page 197

1 Type specimen

Clinton shale, Clinton, Oneida co., N. Y.

Genus DENDROGRAPTUS Hall

Dendrograptus rectus sp. nov.

Page 145

2 Type specimen (holotype)

Clinton shale, Clinton, Oneida co., N. Y.

Genus PALAEODICTYOTA Whitfield

See plates 6, 7

Palaeodictyota clintonensis sp. nov.

See plate 6, figure 5; plate 7, figures 5, 6

Page 203

3 Most complete specimen observed

Clinton shale, Clinton, Oneida co., N. Y.

All figures are drawn in natural size; the originals are in the New York State Museum.

GRAPTOLITES

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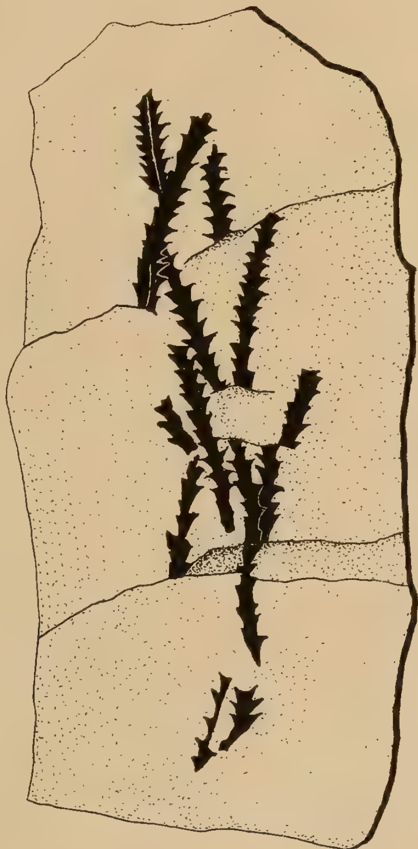

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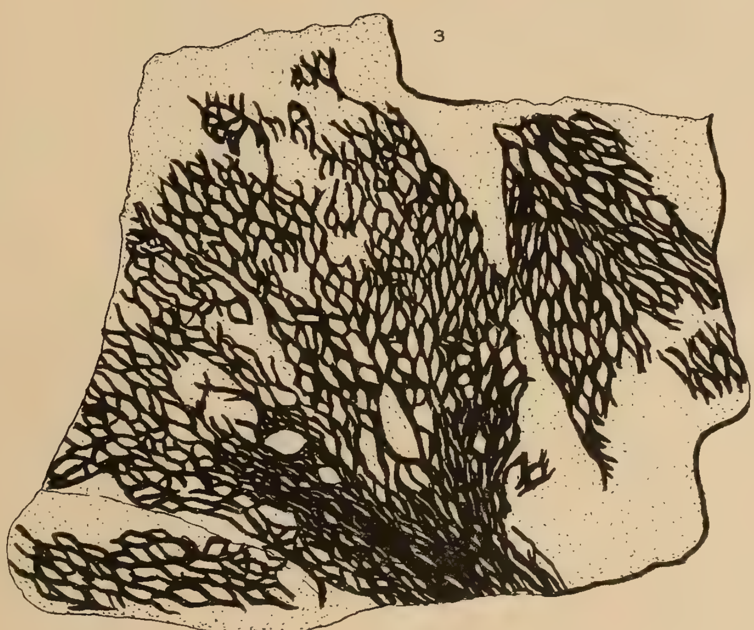


R. R. del.

PLATE 9

Genus MASTIGOGRAPTUS nov.

See plates 10–12

Mastigograptus simplex (Walcott)

See plate 12, figures 3–5

Page 218

1 Most complete rhabdosome observed

Utica shale, Holland Patent, N. Y.

Mastigograptus tenuiramosus (Walcott)

See plate 10, figure 1; plate 11, figures 1–4; plate 12, figures 1, 2

Page 216

2 Rhabdosome showing the typical habitus of the form. The dense mass of delicate terminal branches is omitted

3 Fragment of large rhabdosome with part of main stem

Utica shale, Holland Patent, N. Y.

All figures are drawn in natural size; the originals (topotypes) are in the New York State Museum.

GRAPTOLITES

R. R. del.

PLATE 10

Genus MASTIGOGRAPTUS nov.

See plates 9, 11, 12

Mastigograptus tenuiramosus (Walcott)

See plate 9, figures 2, 3; plate 11, figures 1–4; plate 12, figures 1, 2

Page 216

1 Fragment of rhabdosome with conical appendages
Lower third of Eden shale, Covington, Ky.

Mastigograptus gracillimus (Lesquereux)

Page 219

2 Specimen from type locality (topotype)
Eden shale, bed of Licking river, Covington, Ky.

Mastigograptus circinalis sp. nov.

See plate 12, figures 7, 8

Page 222

3 Fragment of shale with specimens (cotypes)
Utica shale, Rural cemetery, Albany, N. Y.

Genus THAMNOGRAPTUS Hall

See plate 12

Thamnograptus capillaris (Emmons)

See plate 12, figures 9–16

Page 200

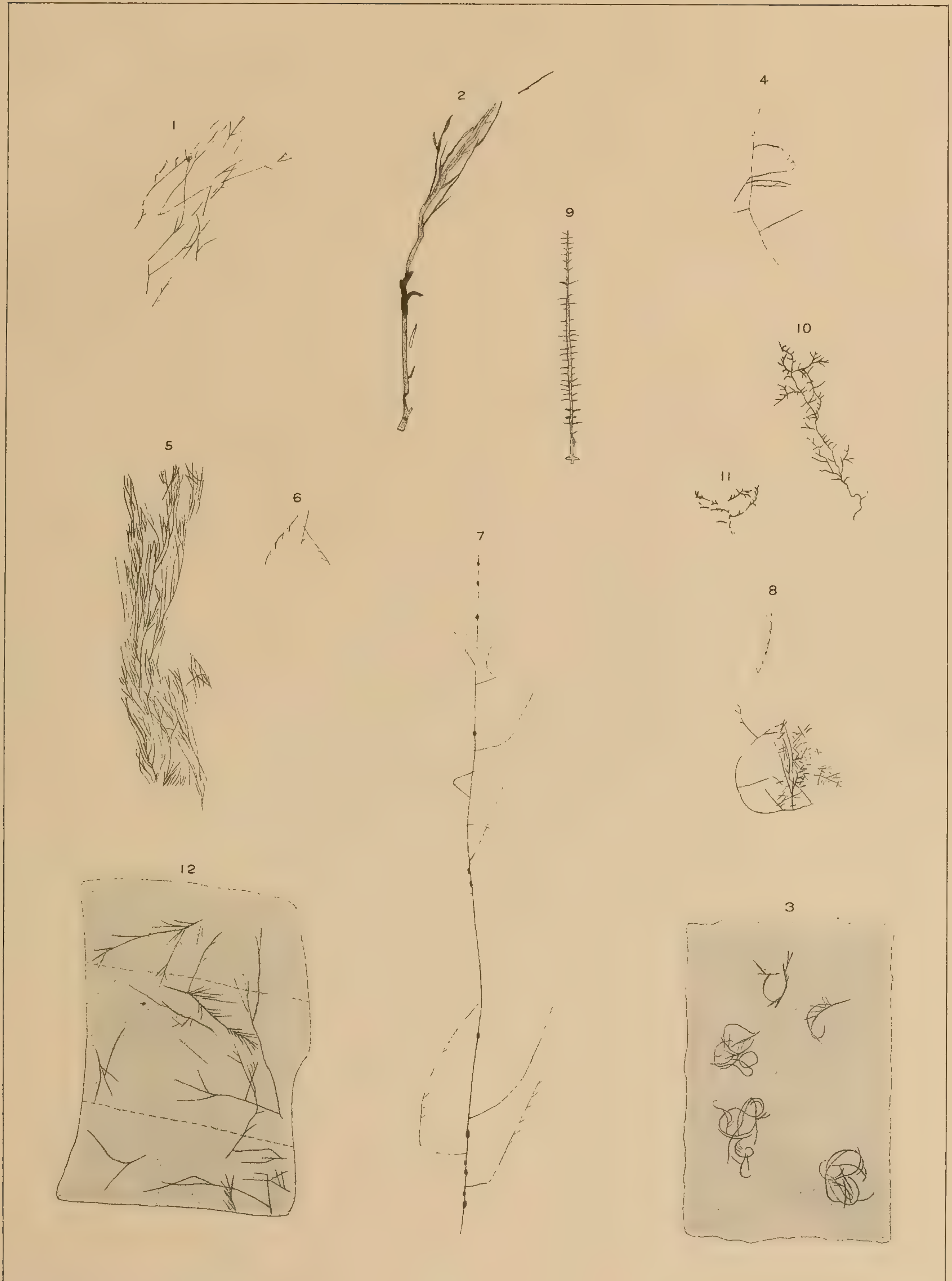
4 Hall's type of Th. capillaris

5 Fragment of rhabdosome with finer branchlets preserved; to illustrate original habitus of form

6 Branch showing the "Rastrites"-aspect and nature of apparent denticles as bases of branches

7 Large distal fragment of main stipe with few secondary branches. Shows nodes of main stipe and "Rastrites"-aspect of secondary branches

GRAPTOLITES



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8 Drifted fragment, showing features of figures 5 to 7

All specimens are from the Normanskill shale at Kenwood near Albany, N. Y., except 5, which is from Mt Moreno

Genus PROTOVIRGULARIA McCoy (?)

See plate 11

Protovirgularia dichotoma McCoy (?)

See plate 11, figures 8, 9

Page 243

9 Fragment resembling Protovirgularia dichotoma McCoy

Drawing made under supervision of Dr Gurley (x 3)

Normanskill shale, Stockport, Columbia co., N. Y.

Genus CHAUNOGRAPTUS Hall

See plate 11

Chaunograptus novellus Hall

See plate 11, figure 5

Page 225

10 One of Hall's type specimens (cotype)

Waldron shale, Shelby co., Indiana

Chaunograptus gemmatus sp. nov.

See plate 11, figures 6, 7

Page 226

11 Only specimen known (holotype)

Utica shale, Dolgeville, Herkimer co., N. Y.

Chaunograptus ? rectilinea sp. nov.

Page 227

12 Only specimen known (holotype)

Basal Utica shale, Van Schaick island, Cohoes, N. Y.

All figures are drawn in natural size except figure 9 (x 3); the originals of figures 1 and 2 are in the Ulrich collection; that of figure 4 is in the American Museum of Natural History; that of figure 9 in the National Museum; the remainder are in the New York State Museum.

PLATE 11

Genus MASTIGOGRAPTUS nov.

See plates 9, 10, 12

Mastigograptus tenuiramosus (Walcott)

See plate 9, figures 2, 3; plate 10, figure 1; plate 12, figures 1, 2

Page 216

1 Enlargement (x 5) of group of fragments of branches to show the arrangement and character of the conical appendages

2 Further enlargement (x 7) to show the jointed base (at *a*) and the paired smaller appendages

3 Fragment showing connection of larger and smaller appendages (x 7)

4 Fragment showing lateral notches for insertion of smaller appendages (x 7)

The originals are from the Eden shale of Covington, Ky. and in the Ulrich collection.

Chaunograptus novellus Hall

See plate 10, figure 10

Page 225

5 Enlargements (x 5) of some of Hall's type specimens to show the shape and arrangement of the thecae

Chaunograptus cf. gemmatus sp. nov.

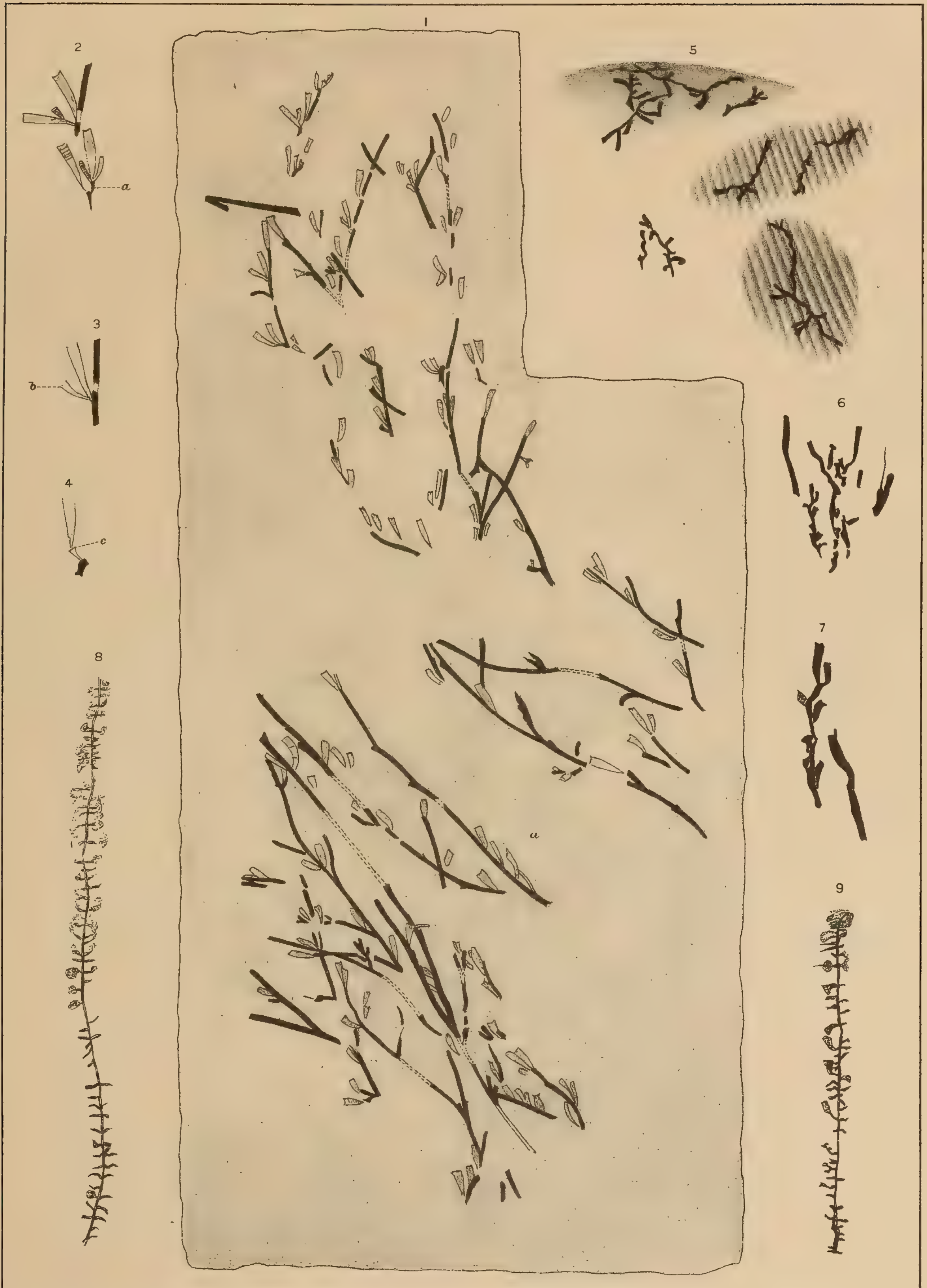
See plate 10, figure 11

Page 226

6 Enlargement (x 5) of the fragments from the Eden shale at Covington, Ky. to show their structure

7 Further enlargement (x 10) of portion of same to show shape and arrangement of thecae

GRAPTOLITES



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Genus PROTOVIRGULARIA McCoy (?)

See plate 10

Protovirgularia dichotoma McCoy (?)

See plate 10, figure 9

Page 243

8, 9 Enlargements (x 5) of the two specimens of this form, observed in the Normanskill shale of Stockport, N. Y. to show the shape of the appendages

The originals of figures 1–4, 6, 7 are in the Ulrich collection; that of figure 5 is in the New York State Museum; those of figures 8, 9 are in the National Museum.

PLATE 12

Genus MASTIGOGRAPTUS nov.

See plates 9–11

Mastigograptus tenuiramosus (Walcott)

See plate 9, figures 2, 3; plate 10, figure 1; plate 11, figures 1–4

Page 216

1, 2 Enlargements (x 5) to show the structure of the branches and the apertures of the thecae
Utica shale, Holland Patent, N. Y.

Mastigograptus simplex (Walcott)

See plate 9, figure 1

Page 218

3–5 Enlargements (x 5) showing the structure of the branches and the location of the apertures of the thecae
Utica shale, Holland Patent, N. Y.

Mastigograptus arundinaceus (Hall)

Page 221

6 Enlargement (x 5) of type specimen (holotype)
Utica shale, Turin, Lewis co., N. Y.

Mastigograptus circinalis sp. nov.

See plate 10, figure 3

Page 221

7, 8 Enlargements (x 5) of the types showing the thecal apertures and mode of branching
Utica shale, Rural cemetery, Albany, N. Y.

Genus THAMNOGRAPTUS Hall

See plate 10

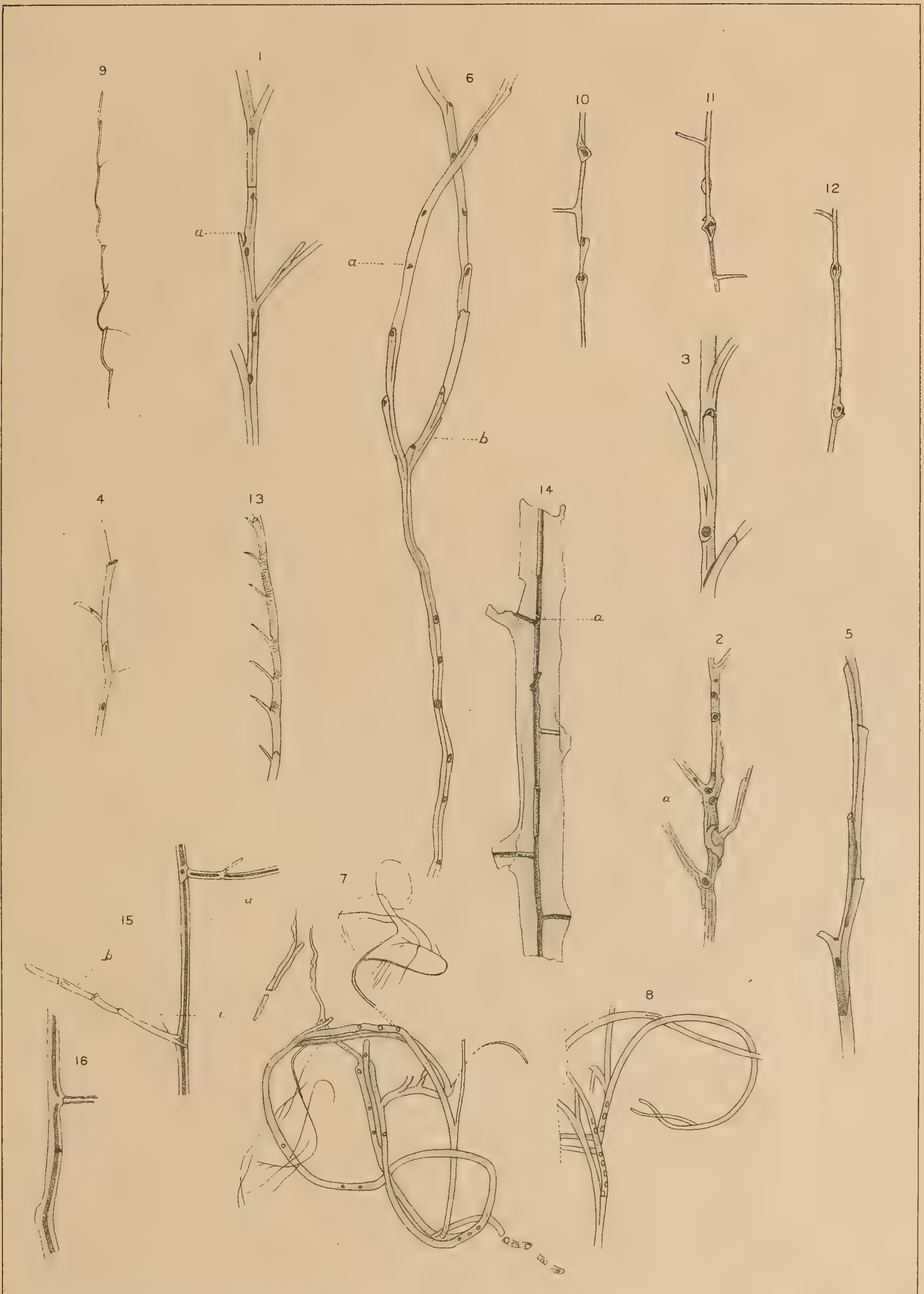
Thamnograptus capillaris (Emmons)

See plate 10, figures 4–8

Page 206

9 Fragment of thin branch, showing its composition of thecae. x 5

10–12 Fragments of branches with nodes. x 5



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13 "Rastrites"-aspect, enlarged (x 5) to show thecal aperture and growth lines

14 Natural section of main stipe, showing original stipe with thecal aperture (a) and secondary thickening. x 5

15 Fragment of rhabdosome, showing secondary thickening of stipe and composition of branches of thecae. x 5

16. Fragment of stipe with secondary thickening. x 5

Normanskill shale, Kenwood, Albany co., N. Y.

All figures are enlarged x 5; the originals of figures 6 and 14 are in the American Museum of Natural History, all the others in the New York State Museum.

PLATE 13

Genus CORYNOIDES Nicholson

Corynoides calicularis Nicholson

Page 234

1 Group of specimens in natural size[1]

6–8 Specimens showing the structure of the rhabdosome; the sicular and the apertural spines or appendages. x 5

Normanskill shale, Glenmont, Albany co., N. Y.

Corynoides gracilis Hopkinson

Page 237

2 Group of typical specimens. Natural size

Transition shale, Sandy Hill, Saratoga co., N. Y.

12 Young rhabdosome, consisting of sicula and one theca. x 5

15 Rhabdosome, showing distinctly its composition of three thecae. x 5

16 Specimen, showing the sicula and three thecae, as well as the apertural spines. x 5

The originals of figures 12 and 16 are from the Normanskill shale at the Lansingburg power house; that of figure 15 is from the zone of Diplogr. amplexicaulis, Ruscher's quarry, Troy, N. Y.

Corynoides gracilis mut. **perungulatus nov.**

Page 239

3 Group of typical specimens (cotypes). Natural size

9–11, 13 Different aspects of typical rhabdosomes, showing the distal appendages. x 5

14 A young rhabdosome. x 5

The originals of figures 3, 9, 10, 11, 13 are from the Normanskill shale at Glenmont, N. Y.; that of figure 14 from the same horizon at Speigletown near Troy.

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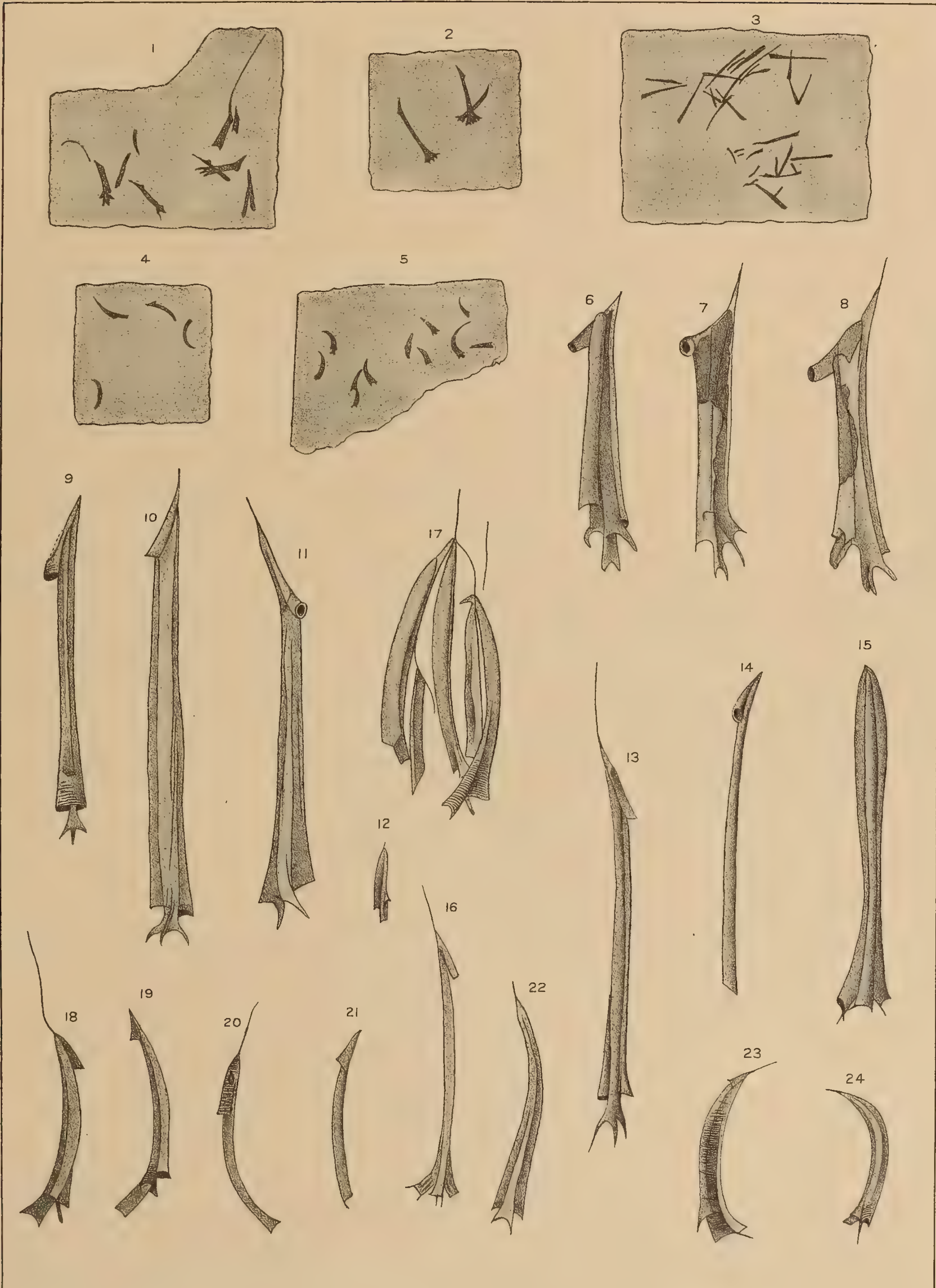
1 The specimens in this and the following groups are in the reproductions too wide by the width of the outlines.

GRAPTOLITES



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Corynoides curtus Lapworth

Page 240

4 Group of typical specimens. Natural size

17 Group of rhabdosomes, apparently belonging to one synrhabdosome. x 5

18, 19 Typical mature specimens, showing the small sicula. x 5

20, 21 Younger specimens with but one theca. x 5

Utica shale, Rural cemetery, Albany, N. Y.

Corynoides curtus var. **comma** nov.

Page 242

5 Group of typical specimens (cotypes). Natural size

22 Largest specimen observed. x 5

23, 24 Typical mature specimens (types). x 5

Lower Utica shale, Mechanicville, N. Y.

All the originals are in the New York State Museum.

PLATE 14

Genus DIDYMOGRAPTUS McCoy

Didymograptus subtenuis (Hall)

Page 253

1, 2 Type specimens (cotypes) redrawn in natural size
Normanskill shale, Kenwood, N. Y.

Didymograptus sagitticaulis Gurley

Page 247

3 Type specimen (cotype) of D. sagittarius redrawn in natural size
Normanskill shale, Kenwood, N. Y.

Didymograptus serratulus (Hall)

Page 251

4 One of the type specimens (cotype) redrawn in natural size
Normanskill shale, Kenwood, N. Y.

Genus LEPTOGRAPTUS Lapworth

Leptograptus annectans (Walcott)

Page 264

5 Typical specimens from type locality (topotypes). Too wide in reproduction
Utica shale, Holland Patent, N. Y.

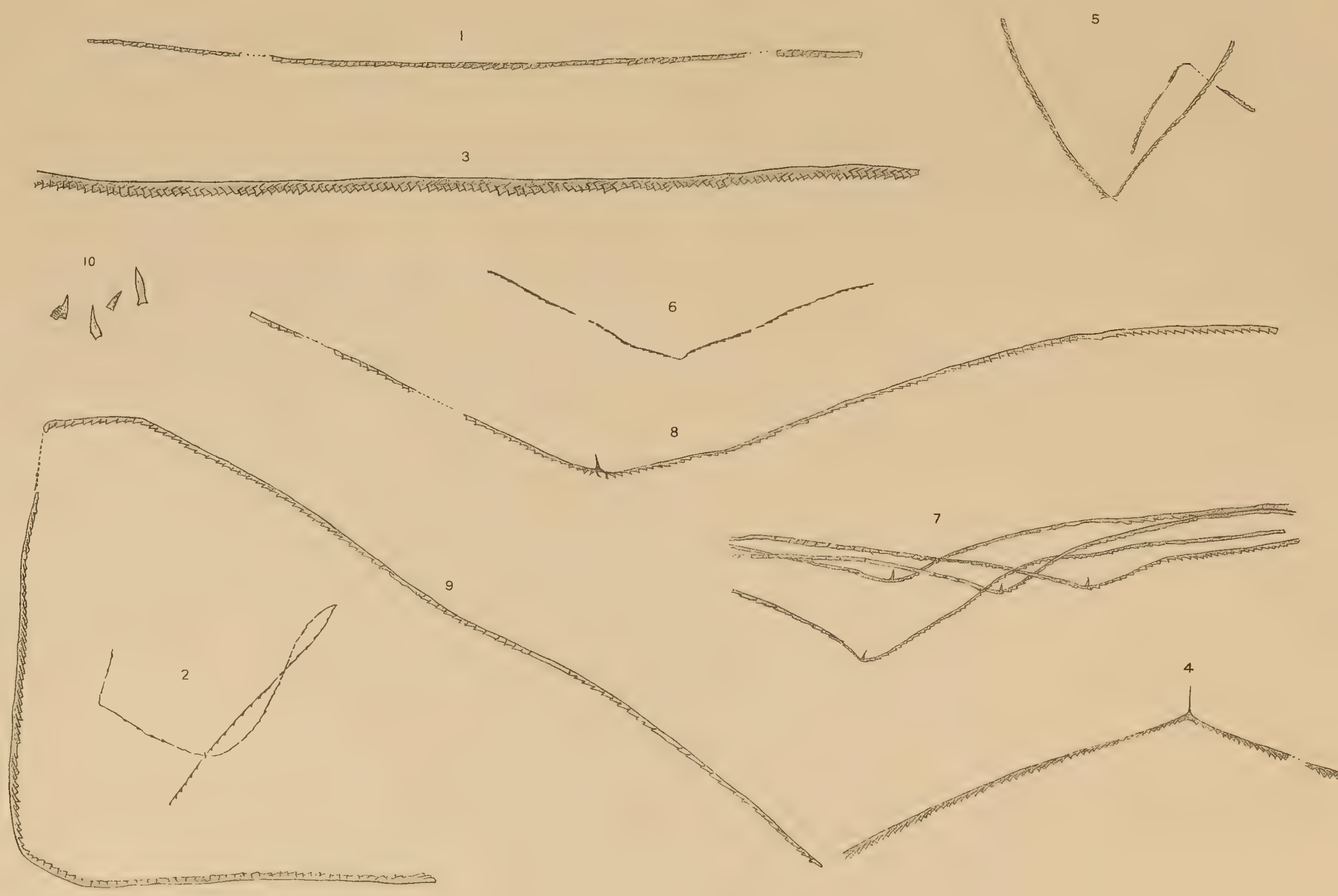
Leptograptus flaccidus (Hall) mut. **trentonensis** nov.

Page 261

6 Narrow specimen
Normanskill shale, Stockport, N. Y.

7 Group of typical specimens (cotypes)
Normanskill shale, Mt Moreno near Hudson, N. Y.

GRAPTOLITES



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Leptograptus flaccidus (Hall) var. **spinifer** Elles & Wood mut. **trentonensis** nov.

Page 262

8 Type specimen (holotype). Natural size

9 Fragment showing great length and width of rhabdosome attained. Natural size

Normanskill shale, Glenmont, N. Y.

Genus AZYGOGRAPTUS Nicholson

Azygograptus ? simplex sp. nov.

Page 258

10 Group of specimens (cotypes)

Normanskill shale, Kenwood, N. Y.

All figures are drawn in natural size. The originals are in the New York State Museum (counterparts of figures 2, 4 also in American Museum of Natural History).

PLATE 15

Genus PLEUROGRAPTUS Nicholson

Pleurograptus linearis (Carruthers)

Page 269

1 Single specimen observed

Utica shale, Holland Patent, N. Y.

Genus AMPHIGRAPTUS Lapworth

Amphigraptus divergens (Hall)

Page 271

2 One of the type specimens (cotype)

Normanskill shale, Kenwood, N. Y.

3 A larger specimen from the type locality (topotype)

Amphigraptus multifasciatus (Hall)

Page 272

4 Copy of the original drawing

Genus SYNDYOGRAPTUS nov.

Syndyograptus pecten sp. nov.

Page 267

5 Group of specimens showing the habitus of the form

6 Rhabdosome with greater number of branches

All figures are drawn in natural size. The originals of figures 1, 4, 5, 6 are in the New York State Museum; that of figure 2 is in the American Museum of Natural History and that of figure 4 has not been located (probably Chicago University).

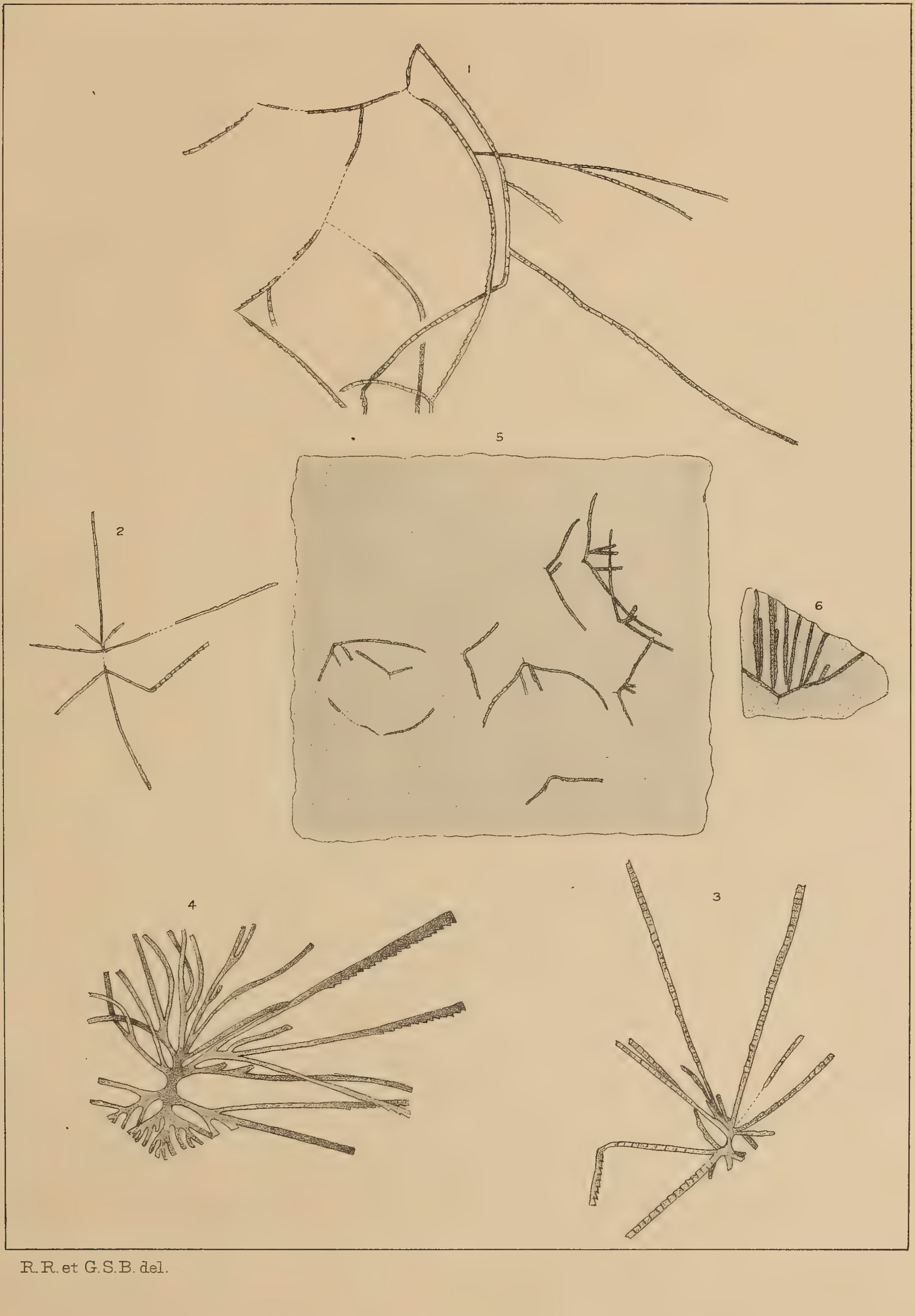

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PLATE 16

Genus NEMAGRAPTUS Emmons

See plate 17

Nemagraptus gracilis (Hall)

Page 277

1 Typical specimen

2 Young rhabdosome

3 Large specimen, showing the length attained by the main stipes

4 Young rhabdosome showing the early development of the secondary branches

9 A variety characterized by extreme slenderness of branches

Normanskill shale, Kenwood, N. Y.

Nemagraptus gracilis var. **approximatus** nov.

Page 287

5 Portion of typical mature specimen (cotype)

6 Younger specimen (cotype)

Normanskill shale, Kenwood, N. Y.

Nemagraptus gracilis var. **distans** nov.

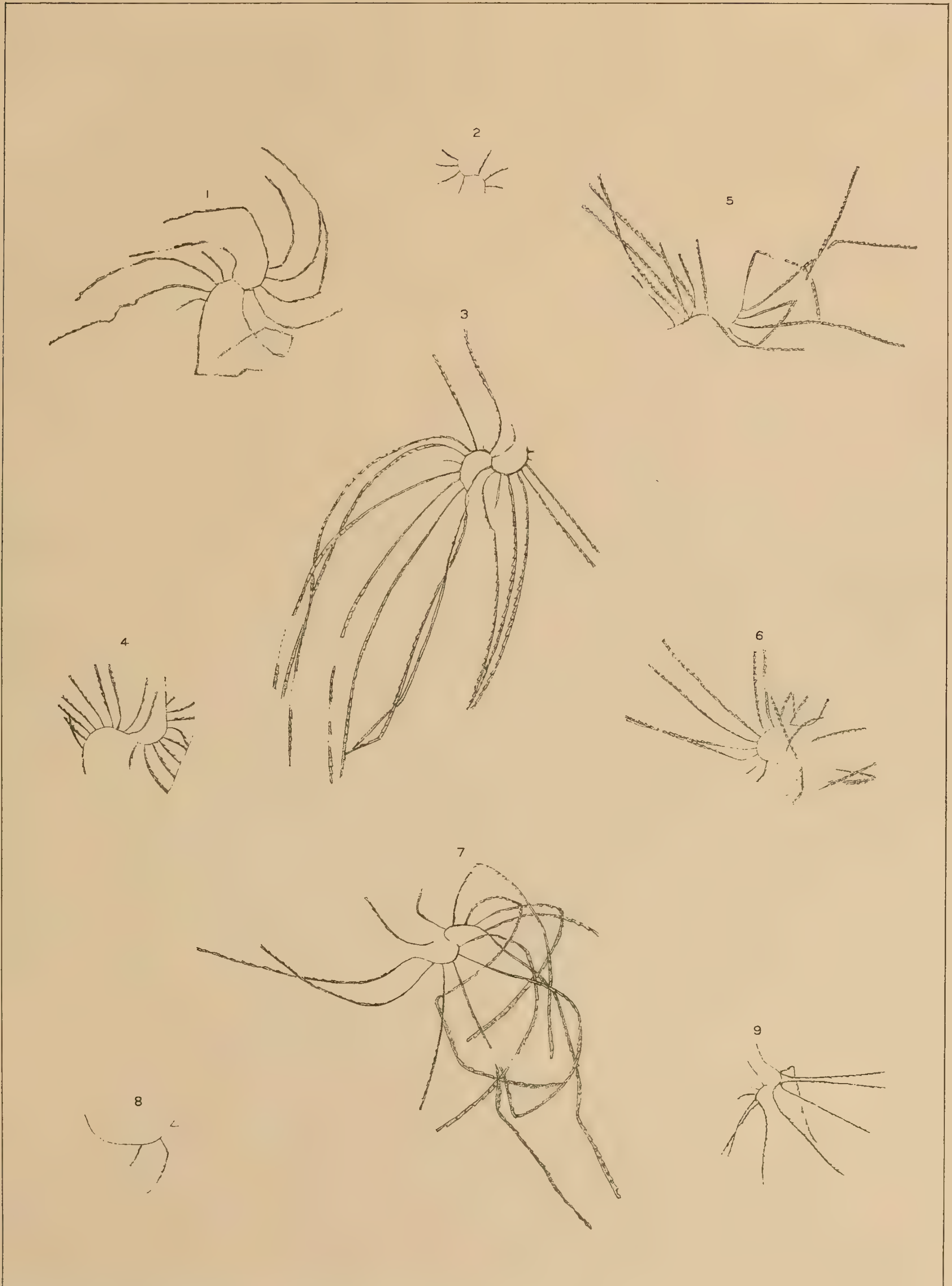
Page 286

7 Type specimen (holotype)

8 Fragment with extremely slender and distant branches

Normanskill shale, Glenmont, N. Y.

All figures are drawn in natural size. The originals are in the New York State Museum.



R.R. et G.S.B. del.

PLATE 17

Nemagraptus gracilis var. **surcularis** (Hall)

Page 282

1 Specimen from the type locality (topotype)

2 Typical specimen

Normanskill shale, Kenwood, N. Y.

Nemagraptus exilis Lapworth

Page 287

3 Typical specimen showing length of branches and sicula

Normanskill shale, Glenmont, N. Y.

4 Young specimen showing lateral spines. From type locality (topotype)

Normanskill shale, Stockport, N. Y.

5 More robust form

Normanskill shale, Glenmont, N. Y.

6 Young individual without secondary branches

Normanskill shale, Stockport, N. Y.

7 Specimen possessing more than usual number of secondary branches

Normanskill shale, Stockport, N. Y.

8, 9 Slender forms with few secondary branches, growing only far from center of rhabdosome

Normanskill shale, Glenmont, N. Y.

Nemagraptus exilis var. **linearis** nov.

Page 290

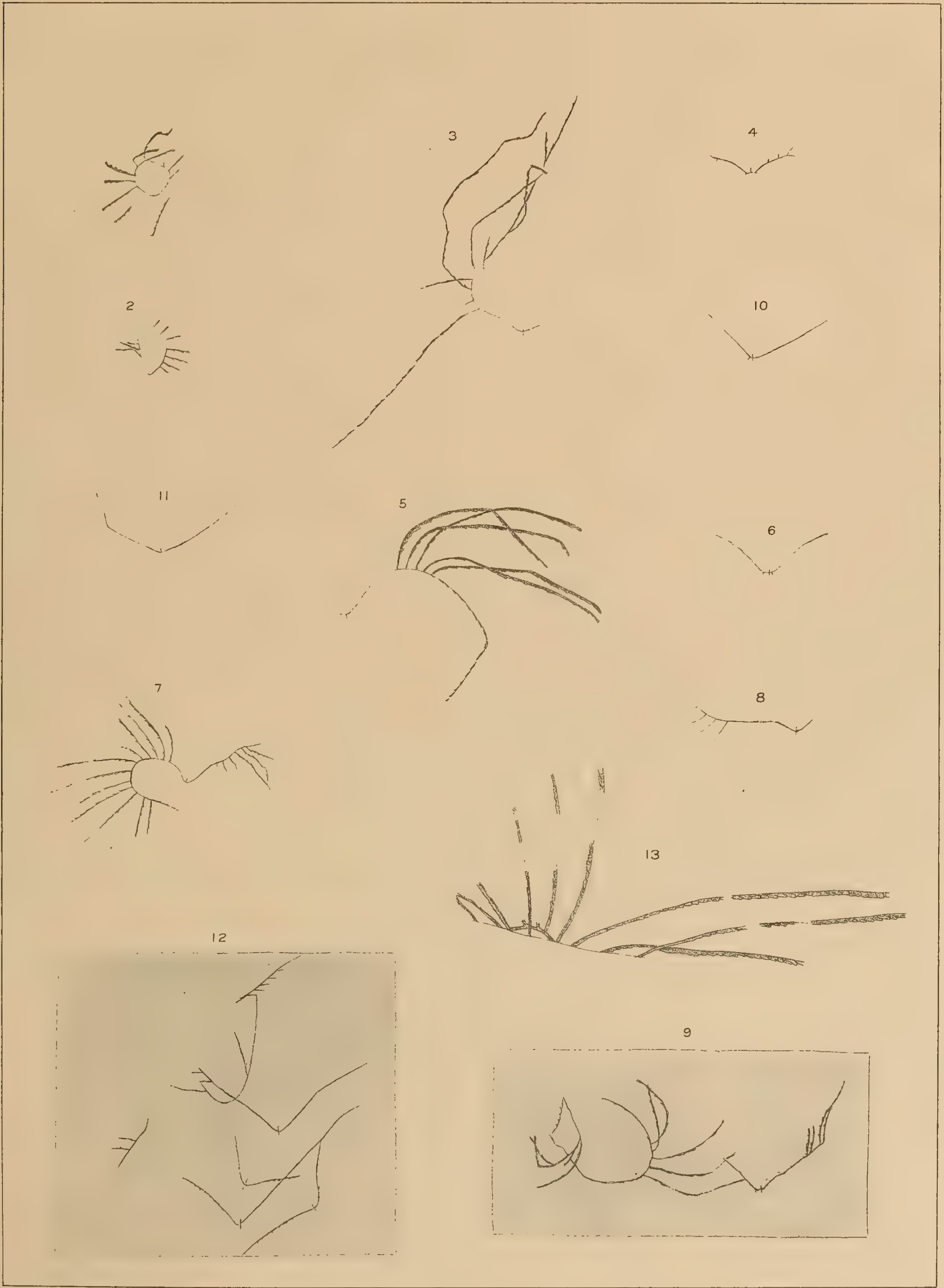
10 Typical specimen (cotype)

Normanskill shale, Speigletown near Troy, N. Y.

11 Typical specimen (cotype)

12 Group of specimens, showing secondary branches (cotypes)

Normanskill shale, Mt Moreno near Hudson, N. Y.



R.R. et G.S.B. del.

Nemagraptus gracilis var. **crassicaulis** Gurley

Page 285

13 Type specimen (cotype)

Normanskill shale, Stockport, N. Y.

All figures are drawn in natural size. The originals of figures 4, 6, 7 and 13 are in the National Museum; the others in the New York State Museum.

PLATE 18

Genus DICELLOGRAPTUS Hopkinson

See plates 19, 20

Dicellograptus cf. **complanatus** Lapworth

Page 294

1 Largest fragment observed. Wrongly reproduced [*see* enl.]
Sylvan shale, Arbuckle mountains, Indian Territory

Dicellograptus mensurans sp. nov.

Page 295

2 Type specimens (cotypes)
Normanskill shale, Glenmont, N. Y.

Dicellograptus divaricatus (Hall)

Page 296

3 Typical specimen
Normanskill shale, Stockport, N. Y.

4 Two specimens with smaller angle of divergence in association
Normanskill shale, Kenwood, N. Y.

Dicellograptus divaricatus var. **salopiensis** Elles & Wood

Page 300

5 Typical specimen
Normanskill shale, Kenwood, N. Y.

6 Extremely slender specimen
Normanskill shale, Stockport, N. Y.

Dicellograptus divaricatus var. **rectus** nov.

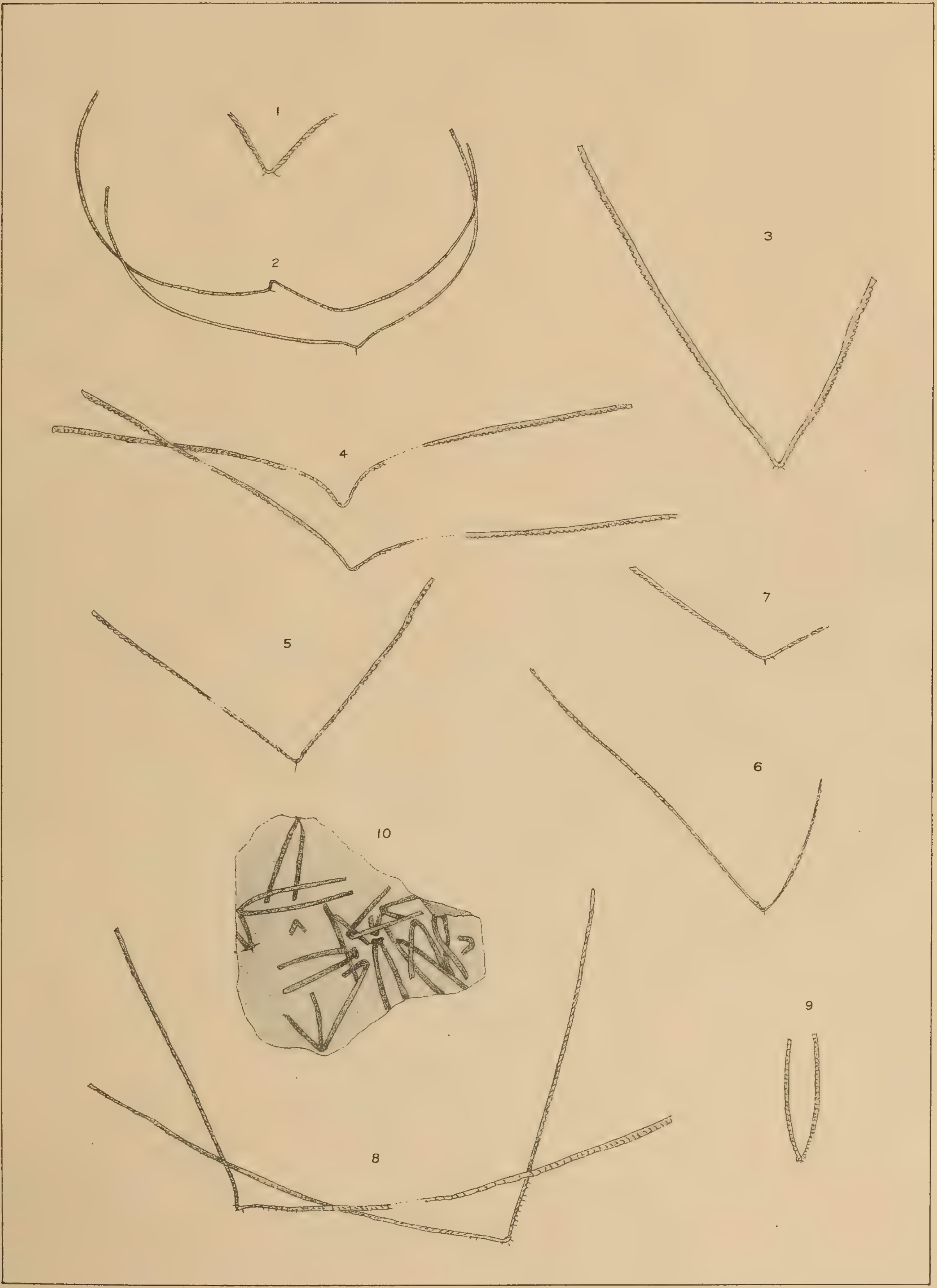
Page 299

7 Typical, though fragmentary specimen (cotype)
Normanskill shale, Glenmont, N. Y.

Dicellograptus divaricatus var. **bicurvatus** nov.

Page 300

8 Type specimens in association (cotypes)
Normanskill shale, Kenwood, N. Y.



R.R. et G.S.B. del.

Dicellograptus intortus Lapworth

Page 302

9 Typical specimen

10 Group of specimens showing the habitus of the form

Normanskill shale, Stockport, N. Y.

All figures are drawn in natural size. The originals of figures 2, 4, 5, 7 and 8 are in the New York State Museum, the remainder in the National Museum.

PLATE 19

Dicellograptus sextans (Hall)

Page 306

1 Group of typical specimens
Normanskill shale, Glenmont, N. Y.

Dicellograptus sextans var. **perexilis** nov.

Page 310

2 Type specimen (holotype).
Normanskill shale, Mt Moreno near Hudson, N. Y.

Dicellograptus smithi sp. nov.

Page 313

3, 4 Groups of associated specimens showing the typical expression of the species; the specimens reproduced in figure 4 being selected as the types

5, 6 Specimens with crossing branches
Trenton shaly limestone, Pratt's Ferry, Bibb co., Ala.

Dicellograptus gurleyi Lapworth

Page 303

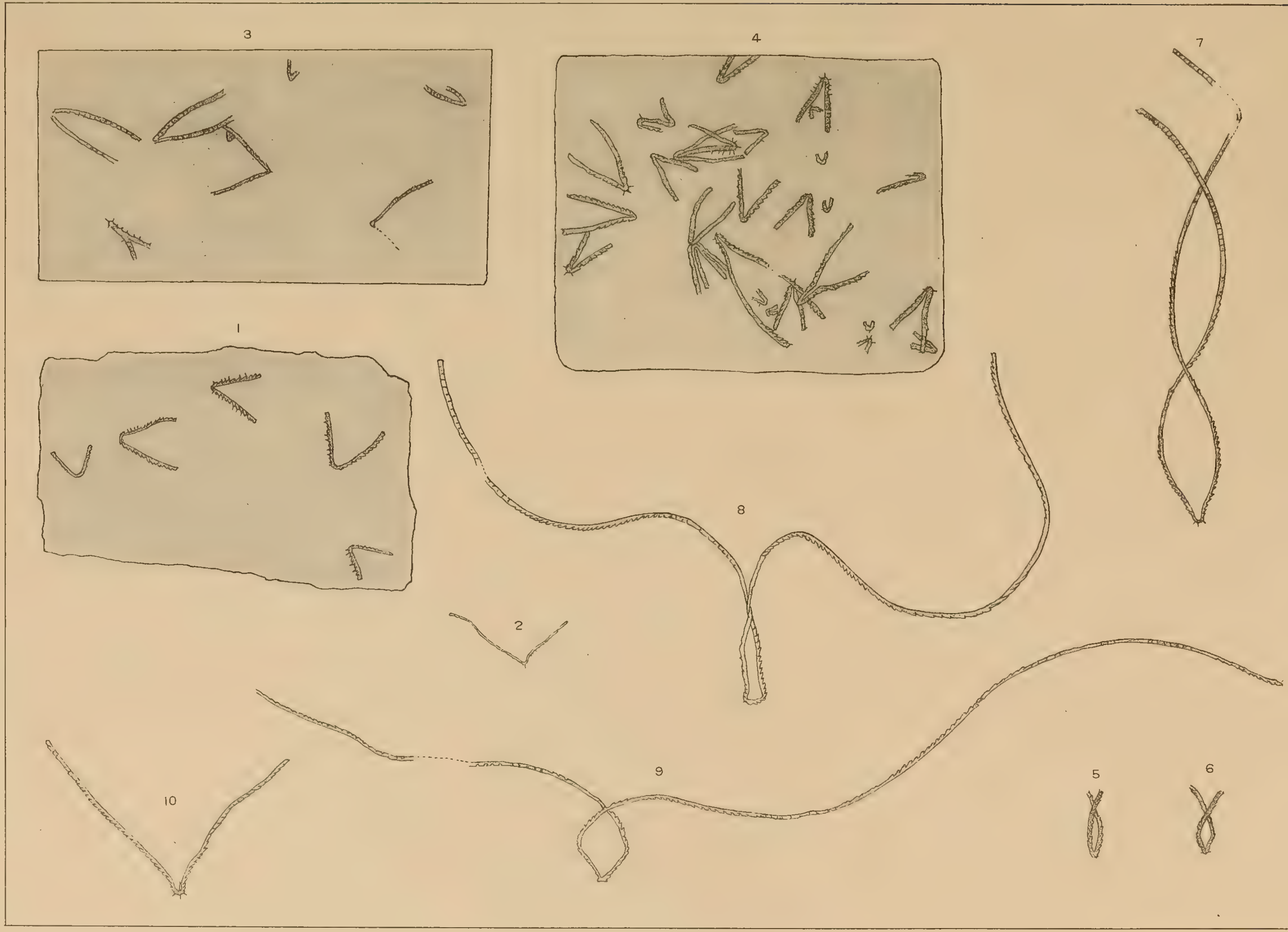
7 Specimen showing a double crossing of the stipes
Normanskill shale, Glenmont, N. Y.

8, 9 Specimens with the typical expression of the species
Normanskill shale, Glenmont, N. Y.

10 Specimen from the type locality (topotype)
Normanskill shale, Stockport, N. Y.

All the figures are drawn in natural size. The originals of figures 1, 2, 7–9 are in the New York State Museum; those of figures 3–6 in the collection of the Geological Survey of Alabama; that of figure 10 in the National Museum.

GRAPTOLITES



R. R. et G. S. B. del.

PLATE 20

Dicellograptus moffatensis (Carruthers) var. **alabamensis** nov.

Page 310

1, 2 Portions of slabs with associated typical specimens, showing the habitus of the form (types on first slab)

Shaly Trenton limestone, Pratt's Ferry, Bibb co., Ala.

Genus DICRANOGRAPTUS Hall

See plates 21-23

Dicranograptus nicholsoni Hopkinson

See plate 21, figure 1

Page 317

3 Group of various growth stages on portion of slab

Utica shale, Saratoga lake, N. Y.

4 Large, typical specimen with biserial portion

5 Very large specimen showing distal reapproachment of branches

Utica shale, Holland Patent, N. Y.

All figures are drawn in natural size. The originals of figures 1, 2 are in the collection of the Geological Survey of Alabama; those of figures 3 and 5 are in the New York State Museum, and that of figure 4 is in the National Museum.

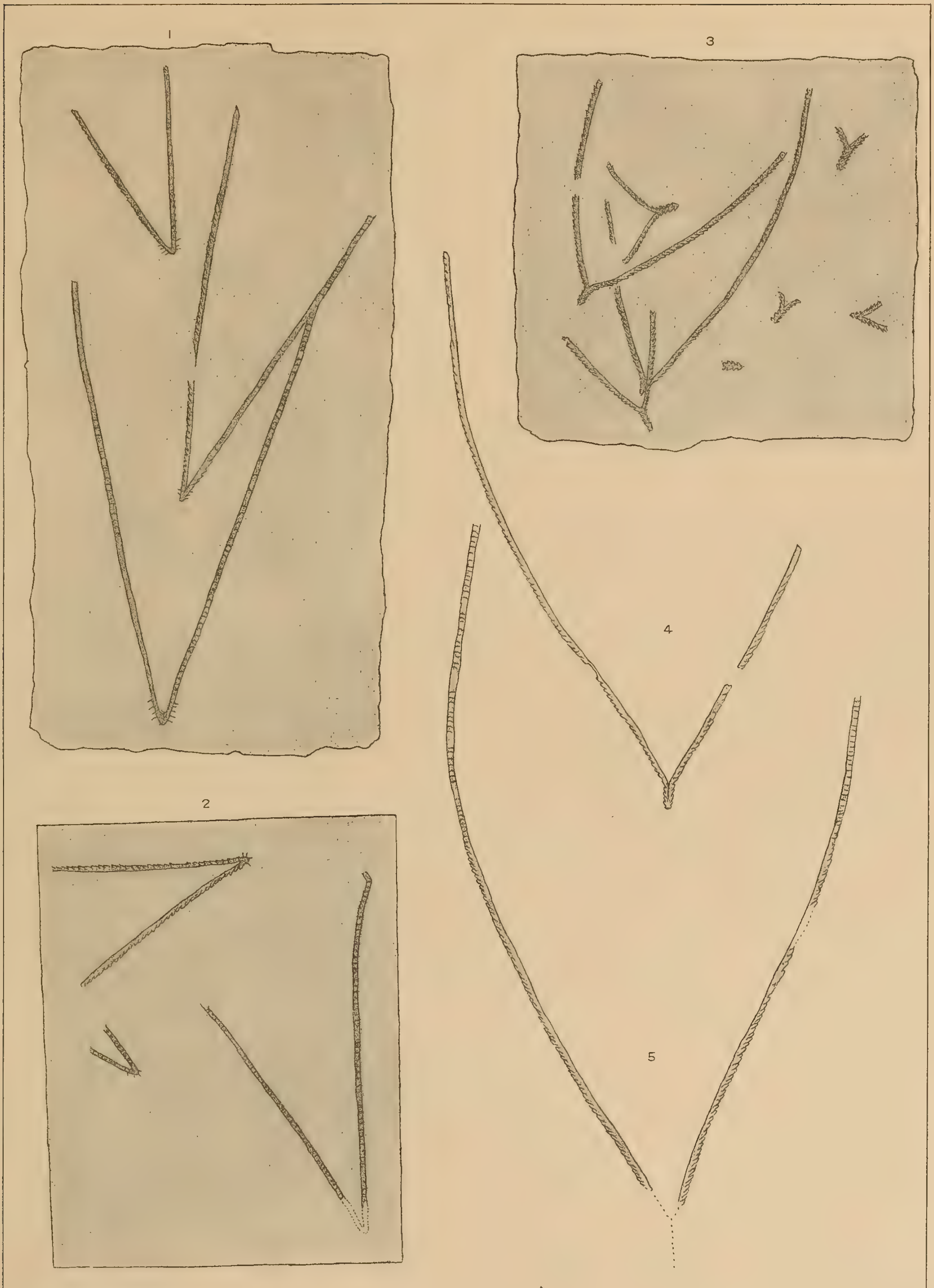


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PLATE 21

Dicranograptus nicholsoni Hopkinson

See plate 20, figures 3-5

Page 317

1 Specimen with very divergent uniserial stipes

Utica shale, Saratoga lake, N. Y.

Dicranograptus nicholsoni var. **parvangulus** Gurley

Page 320

2 Two associated typical specimens

Normanskill shale, Mt Moreno near Hudson, N. Y.

Dicranograptus nicholsoni var. **diapason** Gurley

Page 322

3 Portion of a slab with group of typical specimens

4 Two of the largest specimens observed

Normanskill shale, Glenmont, N. Y.

5 Two associated specimens with a little more divergent uniserial stipes

Normansville shale, Glenmont, N. Y.

Dicranograptus ramosus Hall

See plate 23, figure 1

Page 325

6 Very large specimen with little divergent uniserial stipes

7 Specimen with more divergent stipes

Normanskill shale, Stockport, N. Y.

All figures are drawn in natural size. The originals of figures 1 to 5 are in the New York State Museum ; those of figures 6 and 7 in the National Museum.

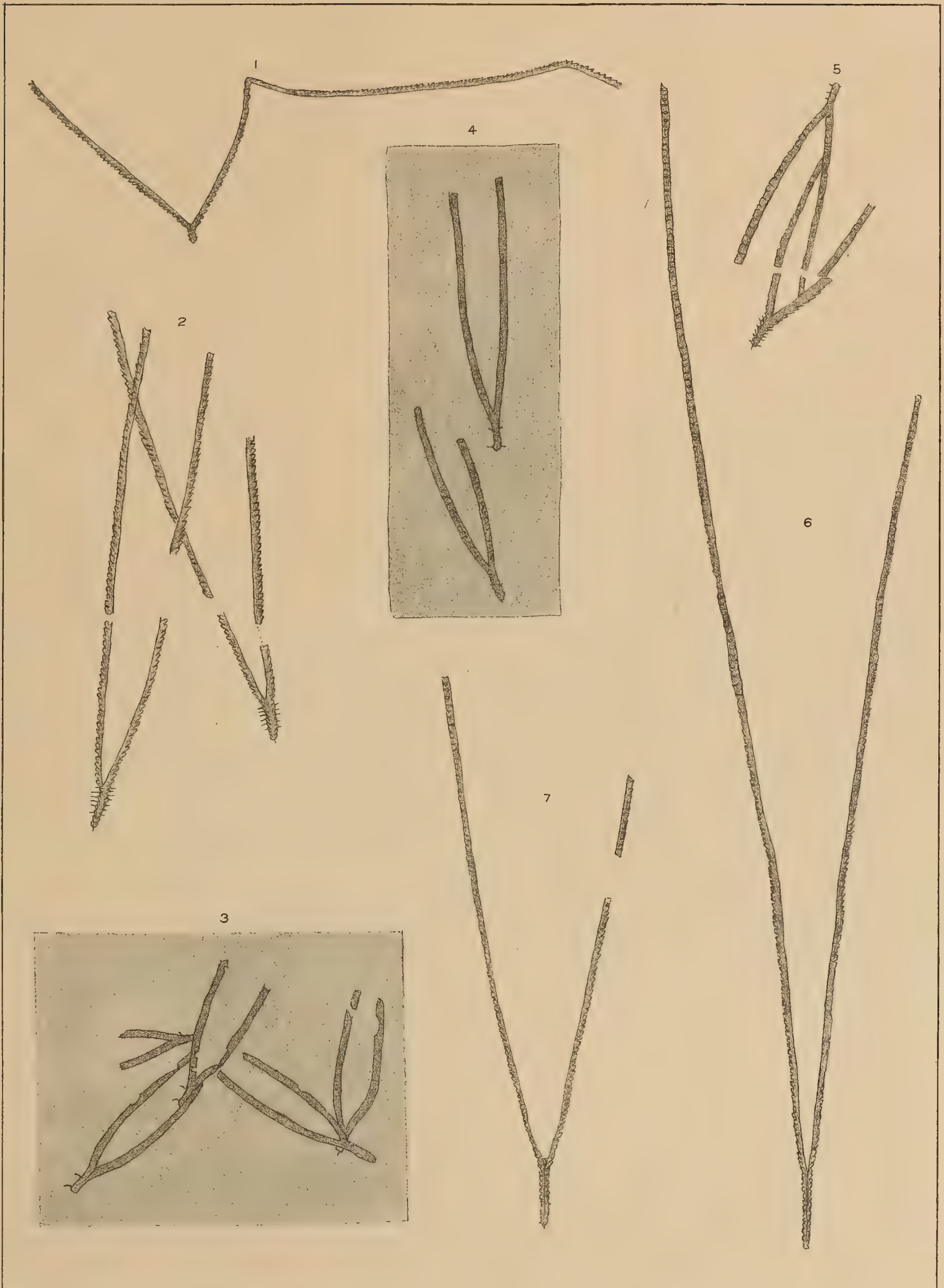

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PLATE 22

Dicranograptus spinifer Lapworth

See plate 23, figures 2, 3

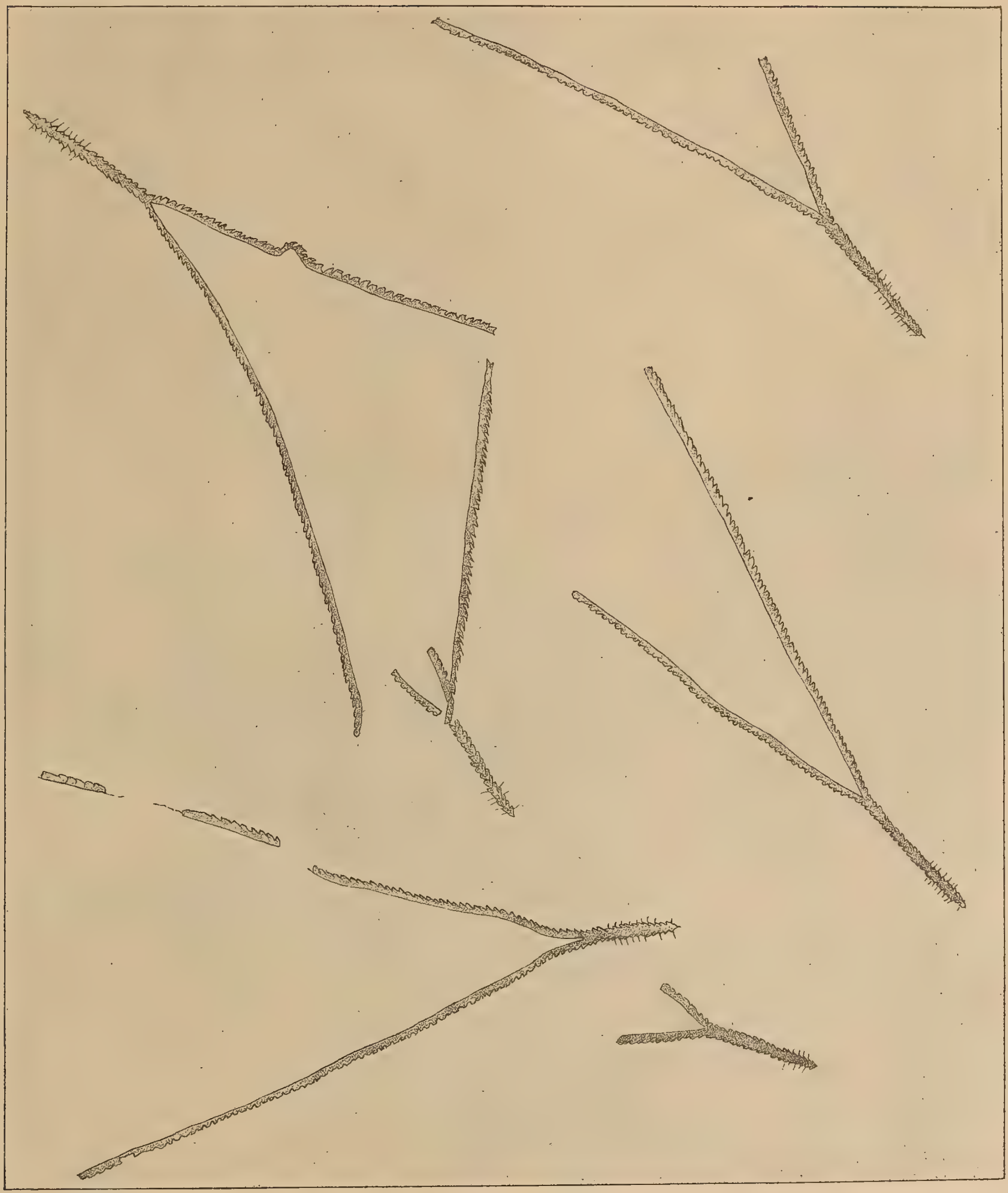
Page 330

1 Portion of slab with a number of specimens showing the usual expression of the form. Natural size

Normanskill shale, Mt Moreno near Hudson, N. Y.

The original is in the New York State Museum.

GRAPTOLITES



R. R. et G. S. B. del.

PLATE 23

Dicranograptus ramosus Hall

See plate 21, figures 6, 7

Page 325

1 Specimen with long biserial portion
Normanskill shale, Mt Moreno, N. Y.

Dicranograptus spinifer Lapworth

Page 330

2 Group of specimens of a late mutation
Utica shale, Oxtungo creek, N. Y.

3 Typical specimen
Normanskill shale, Glenmont, N. Y.

Dicranograptus spinifer var. **geniculatus** nov.

Page 333

4 Specimen with extreme geniculation of the uniserial stipes, and strongly spinose biserial part of rhabdosome (holotype)

5, 6 Specimens with less geniculation, and broad biserial parts
Normanskill shale, Glenmont, N. Y.

Dicranograptus furcatus (Hall)

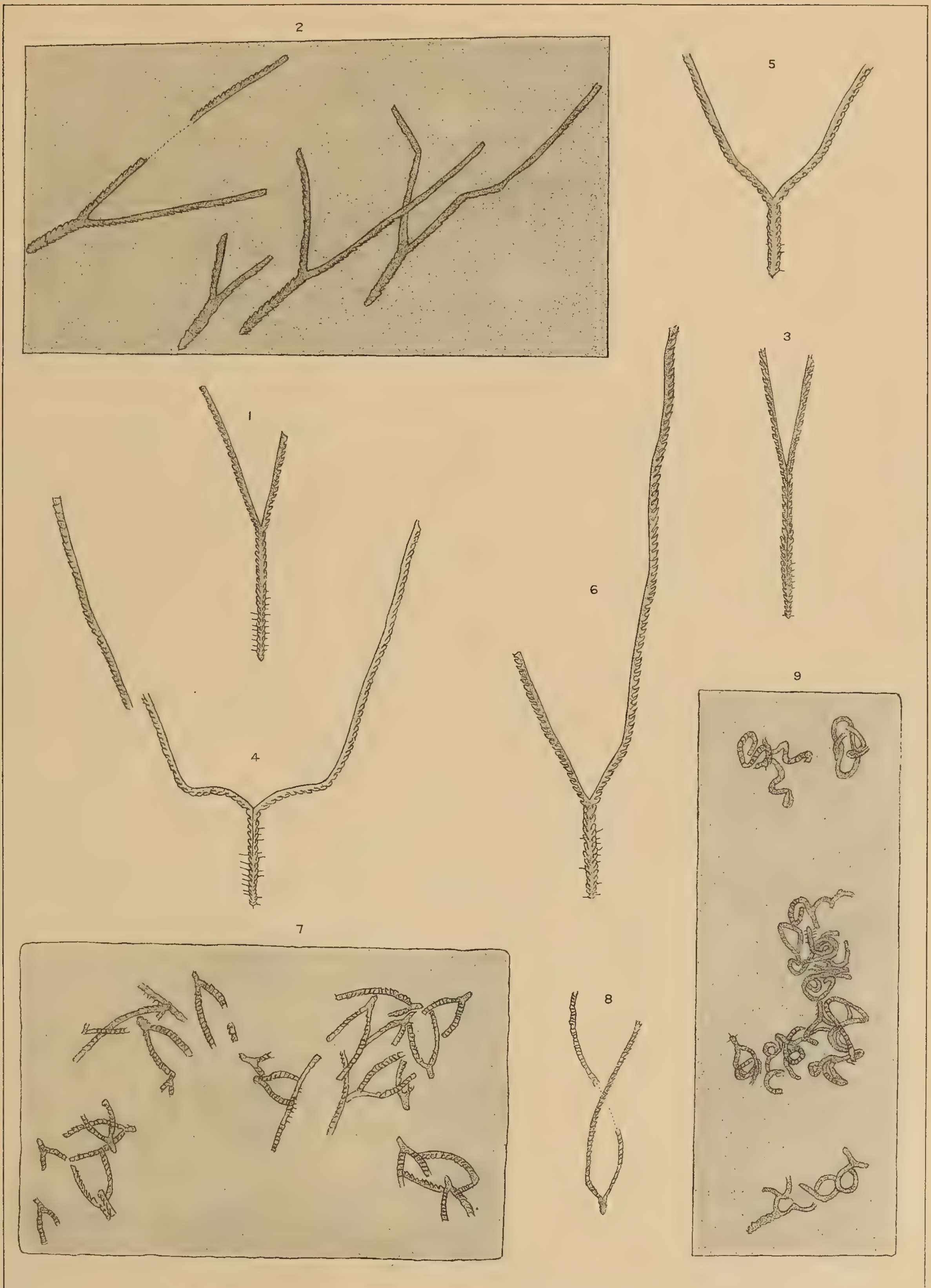
Page 334

7 Group of specimens showing the common appearance
Normanskill shale, Kenwood, N. Y.

Dicranograptus furcatus var. **exilis** nov.

Page 337

8 Type specimen (holotype). Too wide in the reproduction
Normanskill shale, Kenwood, N. Y.



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Dicranograptus contortus sp. nov.

Page 337

9 Portion of slab with numerous specimens showing the characteristic aspect of the form (cotypes)

Normanskill shale, Kenwood, N. Y.

All figures are drawn in natural size. The originals are all in the New York State Museum.

PLATE 24

Genus DIPLOGRAPTUS McCoy

See plate 25

Diplograptus foliaceus (Murchison) var. **incisus** Lapworth

See plate 25, figures 1, 2

Page 347

1 Large typical rhabdosome with long nemacaulus
2 Frontal aspect of rhabdosome
3 Synrhabdosome
4 One of the longest rhabdosomes observed
5 Largest and most complete synrhabdosome observed
6 Rhabdosome with typical character of the var. incisus
7 Small rhabdosome with long virgella
8 Relatively broad rhabdosome

All figures are drawn in natural size. The originals are in the New York State Museum.

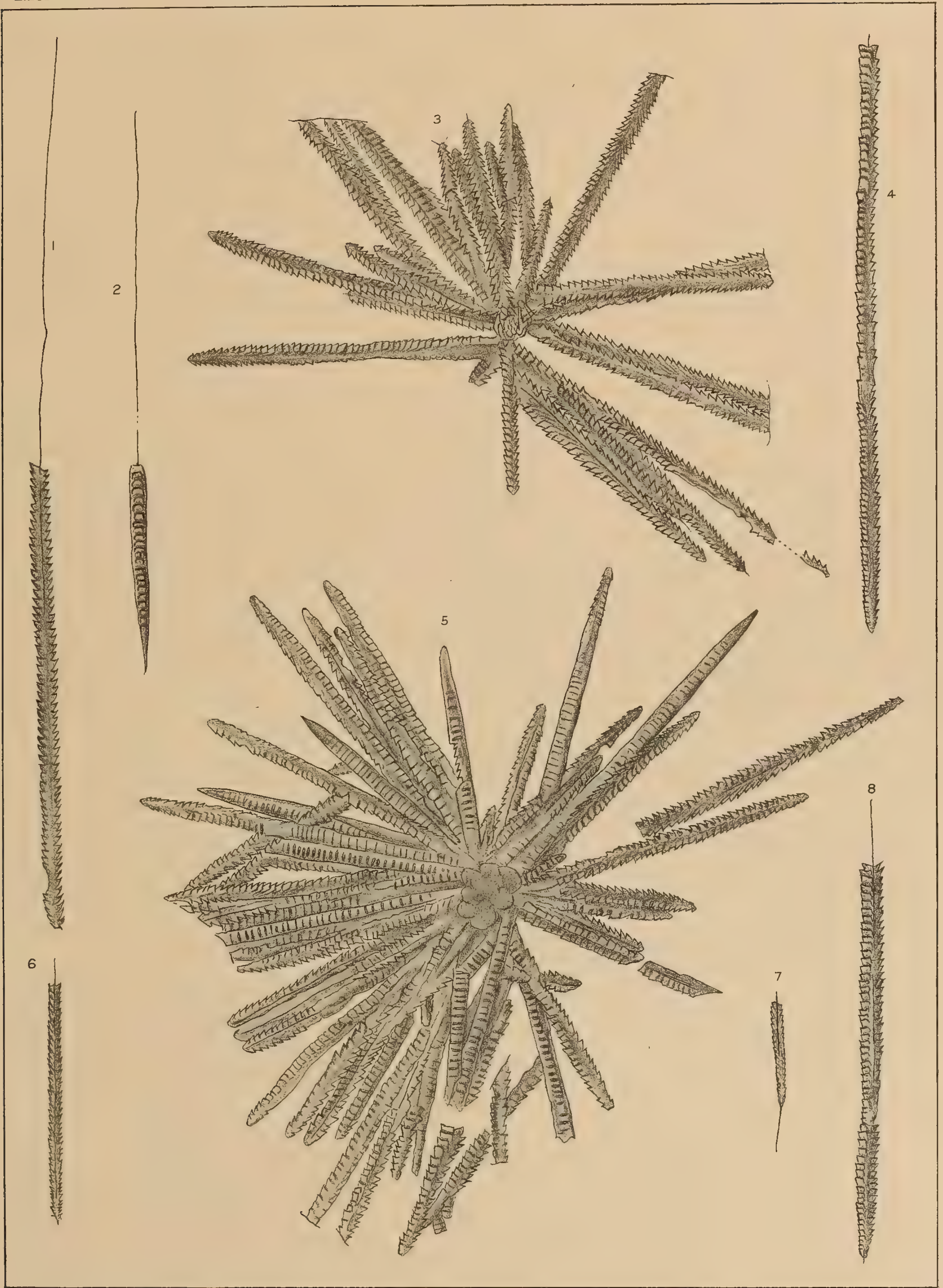

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PLATE 25

Diplograptus foliaceus var. **acutus** Lapworth

Page 349

1 Portion of slab with smaller variety of this form

2 Rhabsodome possessing broad straplike nemacaulus

Normanskill shale, Glenmont, N. Y.

Diplograptus foliaceus var. **alabamensis** nov.

Page 352

3 Rhabdosome, showing the common features of the form (cotype)

Trenton shaly limestone, Pratt's Ferry, Bibb co., Ala.

Diplograptus foliaceus mut. **vespertinus** nov.

Page 352

4 Relatively large rhabdosome (cotype)[1]

Utica shale, Van Schaick island, Cohoes, N. Y.

5 Group of rhabdosomes of the common size (cotypes)

Utica shale, Amsterdam, N. Y.

18 A rhabdosome of the group figured by Hall [v. 1, pl. 72, fig. 1a] from the Lorraine shale at Turin, Lewis co., N. Y. and apparently belonging here.

Diplograptus crassitestus sp. nov.

Page 354

6 Typical rhabdosome (cotype)

Sylvan shale, Arbuckle mountains, Indian Territory

Diplograptus foliaceus McCoy

Page 361

7–9 Three rhabdosomes of " Graptolithus secalinus," showing the different forms resulting according to the angle between the direction of the orogenic stress (direction of pointer) and the axis of the rhabdosome

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[1] An enlargement of a portion of this rhabdosome is shown in text fig. 293 (erroneously brought under the var. acutus).

R. R. et G. S. B. del.

Diplograptus amplexicaulis Hall

Page 361

10 Group of specimens preserved in shale
Transition shale, Sandy Hill, N. Y.

11 Typical rhabdosome preserved in relief
Trenton limestone, Middleville, N. Y.

12 Typical specimen preserved in shale
Transition shale, Sandy Hill, N. Y.

13 Impression of specimen in limestone. Sicular end narrower in original
Trenton limestone, Middleville, N. Y.

Diplograptus amplexicaulis var. **pertenuis** nov.

Page 365

14 Group of typical specimens in demirelief (cotypes)
Normanskill shale, power house at Lansingburg, N. Y.

15, 16 Strongly flattened specimens in shale. These figures are too wide in the reproduction
Upper Trenton shale (zone of Dipl. amplexicaulis), Brothers' quarry, Troy, N. Y.

Diplograptus peosta Hall

Page 372

17 Specimen preserved in relief
Maquoketa shale, Graf, Iowa

Diplograptus angustifolius (Hall)

Page 366

19 Portion of a slab with group of typical specimens
Normanskill shale, Glenmont, N. Y.

20 Large rhabdosome. Too wide in reproduction
Normanskill shale, power house at Lansingburg, N. Y.

Diplograptus euglyphus Lapworth

Page 369

21 A large rhabdosome

Normanskill shale, Stockport, N. Y.

22 Narrower form

Normanskill shale, Glenmont, N. Y.

23 Strongly compressed specimen

Normanskill shale, Speigletown near Troy, N. Y.

Diplograptus euglyphus var. **pygmaeus** nov.

Page 371

24 Portion of synrhabdosome (holotype). Too wide in reproduction by width of outlines

Normanskill shale, power house at Lansingburg, N. Y.

All figures are drawn in natural size. The originals of figures 17 and 18 are in the American Museum of Natural History, those of figures 6 and 21 are in the National Museum, the others in the New York State Museum.

PLATE 26

Genus GLOSSOGRAPTUS Emmons

See plate 27

Glossograptus ciliatus Emmons

See plate 27, figures 1-4

Page 379

1 Small rhabdosome showing numerous curved spines and beginning vesicular inflation of nemacaulus

2 Small rhabdosome with few straight spines and larger inflation

3 Older rhabdosome with both straight and curved spines and relatively large inflation of nemacaulus

4 Specimen with relatively long curved spines

5 Specimen with short spines (broken off through oblique splitting of rock)

Normanskill shale, Glenmont, N. Y.

Glossograptus ciliatus var. debilis nov.

Page 384

6 Typical specimen (cotype)

7 Portion of slab with group of specimens showing the common aspect of the form (cotypes)

Normanskill shale, Mt Moreno near Hudson, N. Y.

Glossograptus ciliatus mut. horridus nov.

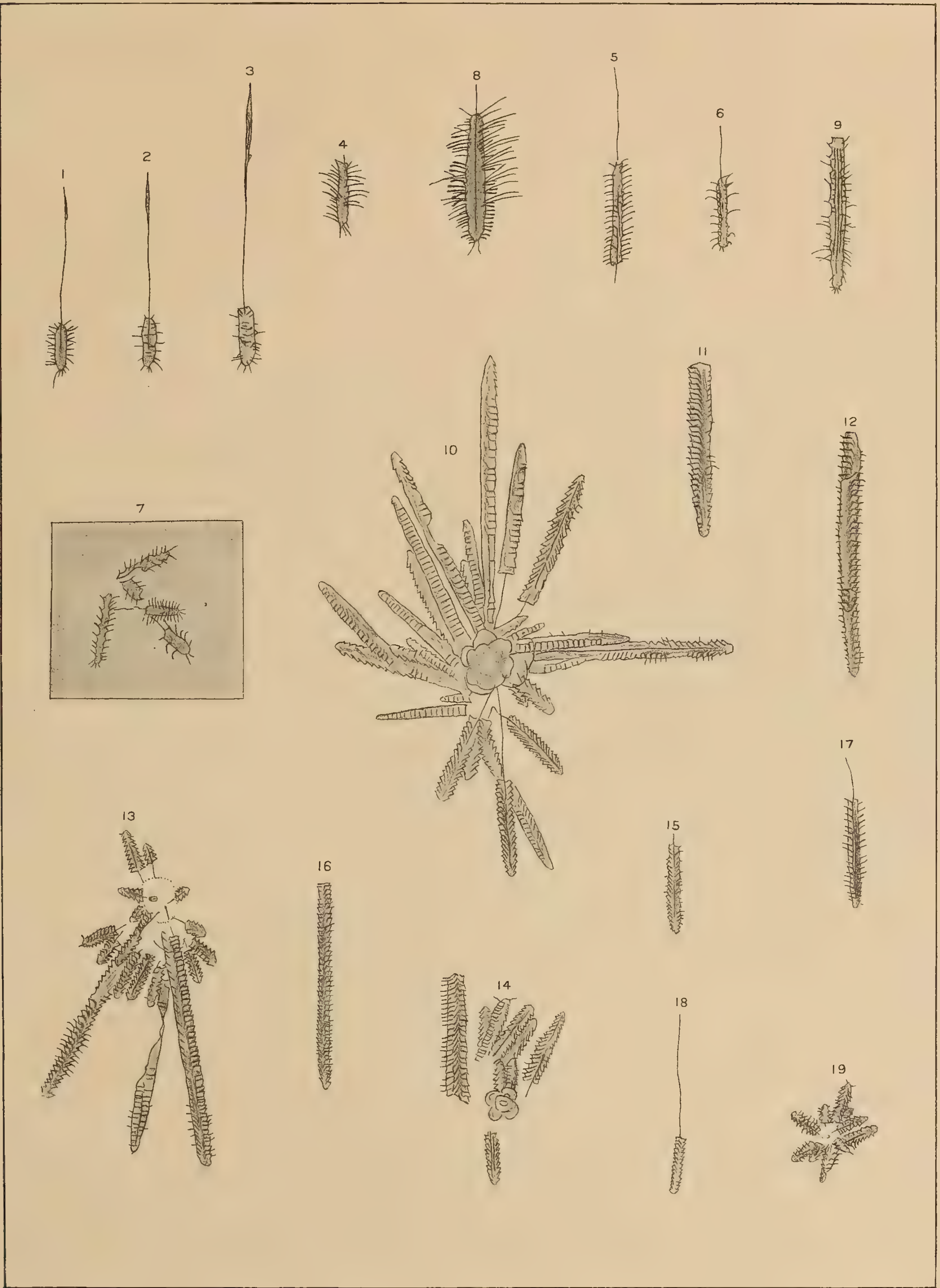
See plate 27, figure 5

Page 383

8 Typical aspect of the form (holotype)

9 Specimen showing three axes

Graptolite shales, Summit, Nev.



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Glossograptus quadrimucronatus (Hall) var. **approximatus** nov.

See plate 27, figures 6, 7

Page 392

10 Most perfect synrhabdosome observed (holotype)
Utica shale, Dolgeville, N. Y.

11 Rhabdosome with distinct apertural spines (paratype)

12 Large rhabdosome, partly preserved as impression and showing the typical characters of the species (paratype)
Utica shale, Oxtungo creek, N. Y.

13 Synrhabdosome, showing two generations of rhabdosomes

14 Synrhabdosome with central organs
Utica shale, Dolgeville, N. Y.

15 Well preserved rhabdosome
Utica shale, dam at Mechanicville, N. Y.

Glossograptus quadrimucronatus mut. **postremus** nov.

Page 394

16 Typical specimen (holotype)
Lorraine (Frankfort) shale, Waterford, N. Y.

Glossograptus whitfieldi (Hall)

Page 394

17 Typical rhabdosome
Normanskill shale, Glenmont, N. Y.

Glossograptus (?) **eucharis** (Hall)

See plate 27, figures 11–13

Page 397

18 Rhabdosome with long nemacaulus, preserved in relief
Utica shale, dam at Mechanicville, N. Y.

19 Synrhabdosome showing primary disk
Utica shale, Dolgeville, N. Y.

All figures are drawn in natural size ; the originals of figures 8 and 9 are in the National Museum, the others in the New York State Museum.

PLATE 27

Glossograptus ciliatus Emmons

See plate 26, figures 1–5

Page 379

1 Rhabdosome, showing both the straight and curved spines

2 Portion of fragment, showing both sets of spines in superposition

3 Rhabdosome, showing thecal apertures and inflation of nemacaulus

4 Specimen showing the double, lateral spines of the apertures

Normanskill shale, Glenmont, N. Y.

Glossograptus ciliatus mut. **horridus** nov.

See plate 26, figures 8, 9

Page 383

5 Enlargement to show the three axes and the ledges of the periderm

Graptolite shale, Summit, Nev.

Glossograptus quadrimucronatus var. **approximatus** nov.

See plate 26, figures 10–15

Page 392

6 Enlargement of portion of macerated rhabdosome to show the ledges and reticulate layer of the periderm

7 Young synrhabdosome, showing central disk and siculae

Utica shale, Dolgeville, N. Y.

Glossograptus quadrimucronatus var. **cornutus** nov.

Page 393

8 Young rhabdosomes, showing the sicula and reflexed growth direction of first theca (cotype)

9 Sicula with first theca (cotype)

10 Sicular extremity of older rhabdosome, showing the relation of first theca to lateral spine (cotype)

Utica shale, Rural cemetery, Albany, N. Y.

GRAPTOLITES

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Glossograptus (?) eucharis (Hall)

See plate 26, figures 18, 19

Page 397

11, 12 Synrhabdosomes showing the central parts
Utica shale, Dolgeville, N. Y.

13 Rhabdosome, showing the apertural spines
Utica shale, Rural cemetery, Albany, N. Y.

All figures are enlarged x 5. The originals are in the New York State Museum with the exception of that of figure 5, which is in the National Museum

PLATE 28

Genus CRYPTOGRAPTUS Lapworth

Cryptograptus tricornis (Carruthers)

Page 443

1 Group of specimens showing the common aspect of the form
Normanskill shale, Mt Moreno near Hudson, N. Y.

2 Frontal view of rhabdosome, showing also character of sicular extremity. Too wide in reproduction

3 Large specimen with long nemacaulus

4 Specimen with inflation of nemacaulus
Normanskill shale, Glenmont, N. Y.

Cryptograptus tricornis mut. **insectiformis** nov.

Page 448

5 Portion of slab with group of specimens showing the typical aspect of the mutation (cotypes)
Lowest Utica shale, Van Schaick island, Cohoes, N. Y.

Genus CLIMACOGRAPTUS Hall

Climacograptus typicalis Hall

Page 407

6 Large typical specimen
Utica shale, Holland Patent, N. Y.

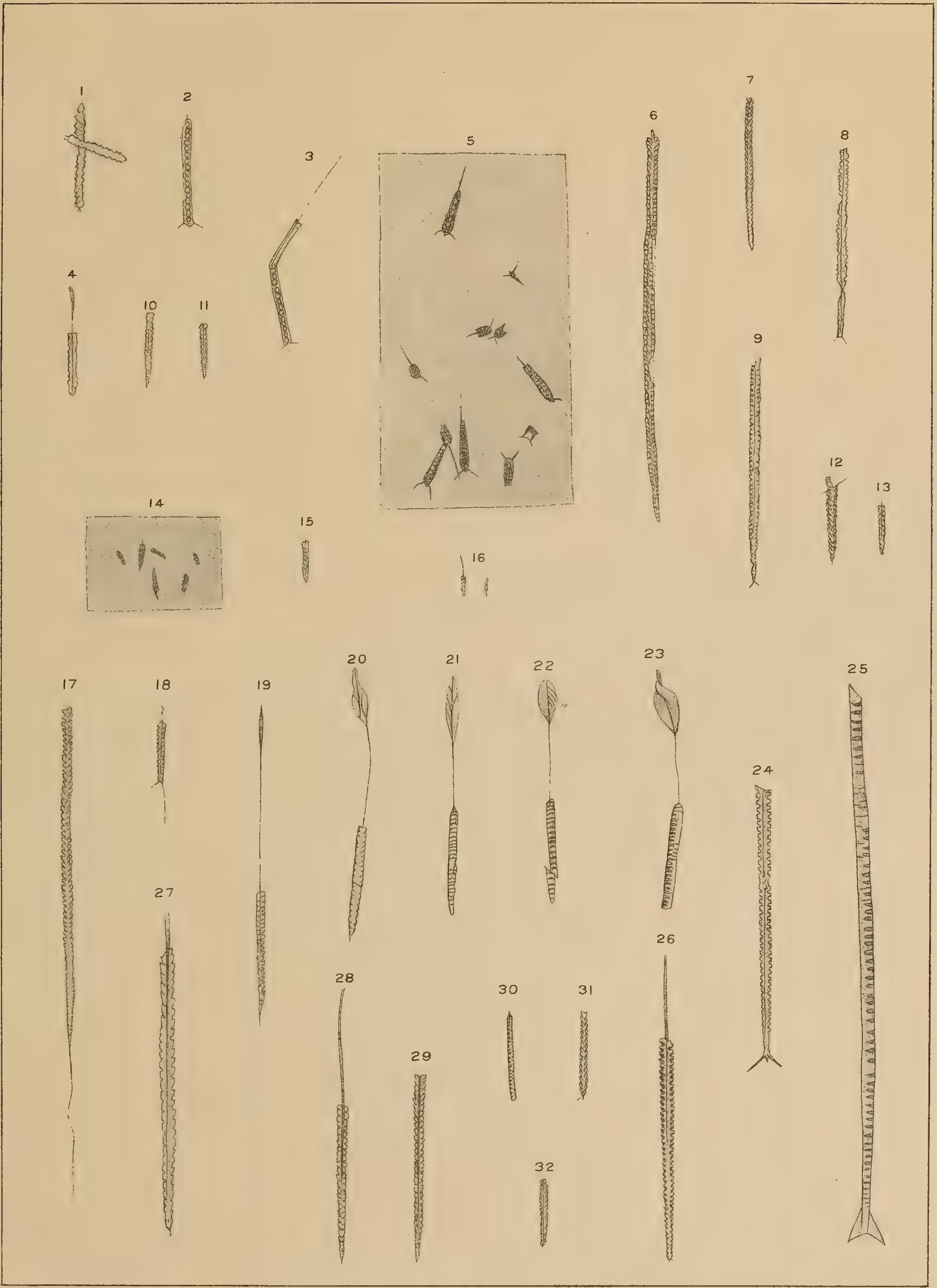
7 A narrow variety
Utica shale, Lees Gulf, Lewis co., N. Y.

Climacograptus typicalis mut. **spinifer** nov.

Page 411

8 Original of Pal. N. Y. v. 1, pl. 72, fig. 2a, 2b, redrawn (cotype)
Utica shale, Ballston, N. Y.

9 Typical rhabdosome (cotype)
Transition shale, Sandy Hill, N. Y.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R. R. et G. S. B. del.

Climacograptus ulrichi sp. nov.

Page 412

10 Typical specimen (holotype)

11 Smaller specimen showing more distinctly the thecae. Incorrectly reproduced [*see* enl.]

Maquoketa shale, Spencer, Mo.

Climacograptus mississippiensis sp. nov.

Page 413

12 Type (holotype)

13 Smaller and less favorably preserved specimen. Incorrectly reproduced

Sylvan shale, Arbuckle mountains, Indian Territory

Climacograptus putillus (Hall)

Page 415

14 Portion of slab with group showing the average size and habit of the form

15 Well preserved, relatively large rhabdosome

Utica shale, Rural cemetery, near Albany, N. Y.

Climacograptus putillus mut. **eximius** nov.

Page 420

16 Two characteristic specimens (cotype)

Normanskill shale, Glenmont and Lansingburg, N. Y.

Climacograptus caudatus Lapworth

Page 438

17 Large, typical rhabdosome

Lowest Utica shale, Mechanicville, N. Y.

18 Young specimen, showing two terminal spines

Utica shale, Hudson river between Troy and Greenbush

Climacograptus parvus (Hall)

Page 426

19–23 Series of specimens showing the common dimensions and different aspects of the rhabdosomes and form of the vesicular inflation of the nemacaulus

Normanskill shale, Glenmont, N. Y.

Climacograptus bicornis Hall

Page 433

24 Typical specimen preserved in relief
Normanskill shale, Kenwood, N. Y.

25 Large rhabdosome showing most common form of appendage of sicular extremity

26 Specimen, presenting peculiar, deeply notched aspect (subscalariform view), due to oblique compression
Normanskill shale, Glenmont, N. Y.

Climacograptus cf. **oligotheca** Gurley

Page 441

27 Well preserved specimen, showing form of thecae and broad straplike nemacaulus
Normanskill shale, Novaculite region of Arkansas

Climacograptus antiquus Lapworth

Page 439

28, 29 Two characteristic specimens showing the form of the rhabdosome and the broad nemacaulus
Talihina formation, Indian Territory

Climacograptus modestus sp. nov.

Page 432

30 Typical specimen (cotype)
Normanskill shale, Mt Moreno near Hudson, N. Y.

Climacograptus scharenbergi Lapworth

Page 428

31 Well preserved shale specimen
Normanskill shale, Mt Moreno near Hudson, N. Y.

Climacograptus scalaris var. annulatus nov.

Page 421

32 Typical specimen (cotype)

Clinton sandstone, Caribou, Me.

All figures are drawn in natural size. The original of figure 8 is in the American Museum of Natural History; those of figures 10 and 11 are in the Ulrich collection; those of figures 12, 13, 27, 28, 29 in the National Museum, the remainder in the New York State Museum.

PLATE 29

Genus MONOGRAPTUS Geinitz

Monograptus clintonensis (Hall)

Page 450

1 Typical (fragmentary) rhabdosome
Clinton shale, Genesee gorge, Rochester, N. Y.

Monograptus priodon (Bronn) mut. **chapmanensis** nov.

Page 454

2 Typical specimen
Siluric sandstone, Chapman Plantation, Aroostook co., Me.

Monograptus beecheri Girty

Page 455

3 Two specimens of average size (cotypes)
New Scotland beds, Indian Ladder, Albany co., N. Y.

Genus CYRTOGRAPTUS Carruthers

Cyrtograptus ulrichi sp. nov.

Page 459

4 Slab with numerous fragmentary specimens (cotypes)
Bainbridge limestone, Bainbridge, Cape Girardeau co., Mo.

Genus RETIOGRAPTUS Hall

See plate 31

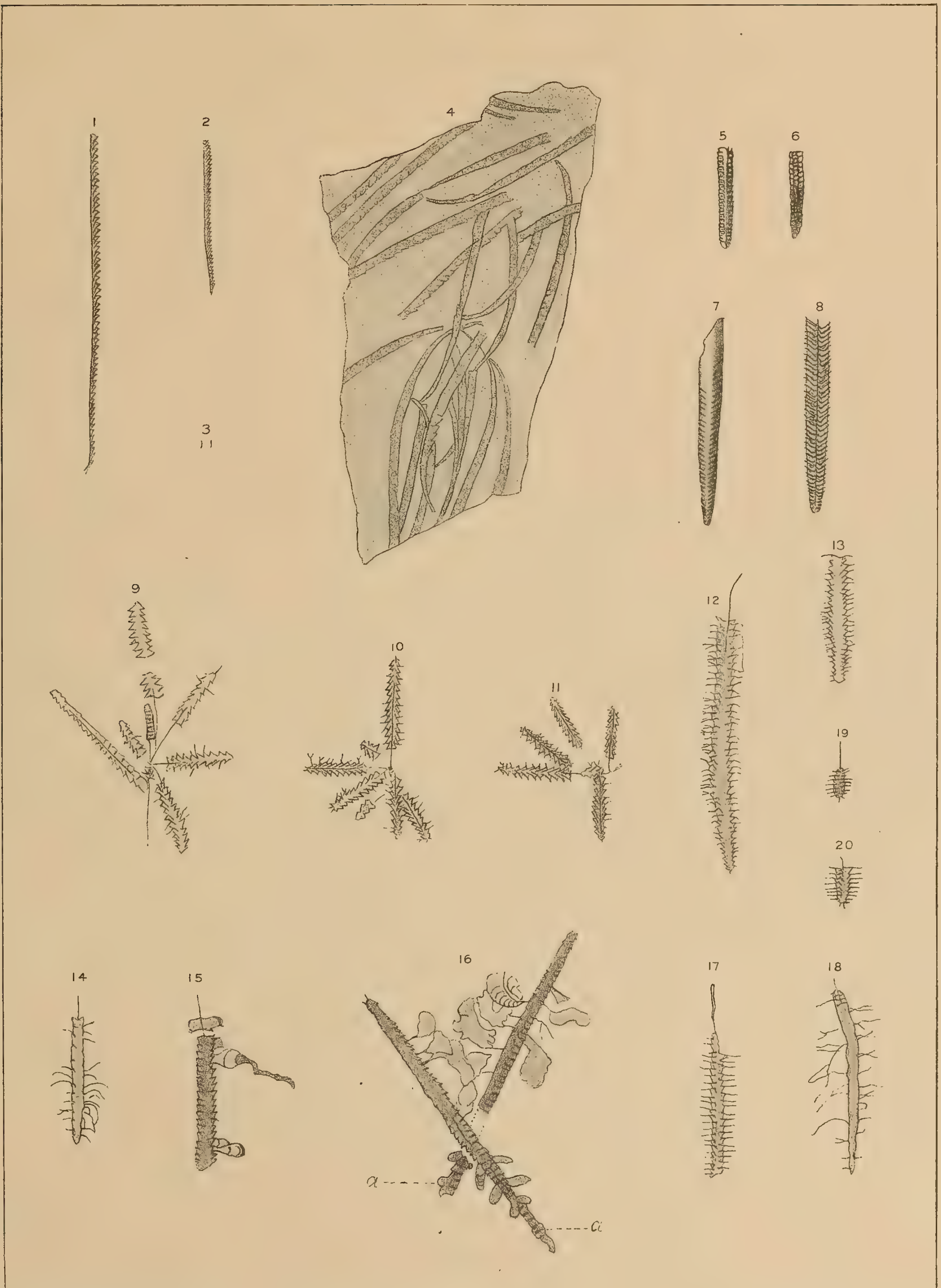
Retiograptus geinitzianus Hall

Page 463

See plate 31, figures 9–17

5 Perfect rhabdosome, retaining periderm and showing form of thecae
6 Specimen showing only the system of ledges
Normanskill shale, Schodack Landing, N. Y.

Memoir 11. N. Y. State Museum Plate 29



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Genus RETIOLITES Barrande

See plate 31

Retiolites geinitzianus Barrande var. **venosus** (Hall)

See plate 31, figures 6-8

Page 469

7 Pyritized specimen, showing the original form of the rhabdosome
Clinton shale, Genesee gorge, Rochester, N. Y.

8 Compressed and split specimen, showing one of the axes and the peridermal ledges
Clinton shale, Palmer's glen, Rochester, N. Y.

Genus LASIOGRAPTUS Lapworth

See plates 30, 31

Lasiograptus mucronatus (Hall)

See plate 30, figures 1-5; plate 31, figures 1-3

Page 479

9-11 Synrhabdosomes showing the common habitus and dimensions of the rhabdosomes
Normanskill shale, Glenmont, N. Y.

Lasiograptus bimucronatus Nicholson

See plate 30, figures 6-8; plate 31, figure 4

Page 481

12 Large complete rhabdosome

13 Smaller specimen, showing the common aspect of the form

14 Specimen retaining the extrathecal fibers and traces of periderm
Normanskill shale, Mt Moreno near Hudson, N. Y.

15 Specimen showing the connection of fibers and nemacaulus

16 Hall's original of decade 2, plate 28, figure 16 redrawn
Normanskill shale, Kenwood near Albany, N. Y.

17 Specimen showing straight rigid fibers and inflation of nemacaulus

18 Specimen with very long extrathecal fibers
Normanskill shale, Mt Moreno near Hudson, N. Y.

Lasiograptus bimucronatus mut. **timidus** nov.

Page 483

19 Small typical specimen

Utica shale, Dolgeville, N. Y.

20 Larger specimen with long straight fibers

Utica shale, Flat creek near Mohawk, N. Y.

All figures are drawn in natural size. The original of figure 3 is in Yale University Museum, that of figure 4 in the Ulrich collection; that of figure 16 in the American Museum of Natural History, and the remainder are in the New York State Museum.

PLATE 30

Genus LASIOGRAPTUS Nicholson

See plates 28, 30

Lasiograptus mucronatus (Hall)

See plate 29, figures 9–11; plate 31, figures 1–3

Page 479

1 Specimen showing the network of finer extrathecal fibers

Normanskill shale, Mt Moreno near Hudson, N. Y.

2 Macerated specimen, retaining the horizontal ledges of the periderm

3 Enlargement of portion of Hall's type of decade 2, plate B, figure 8

Normanskill shale, Kenwood, N. Y.

4 Small specimen showing distal connection of fibers

5 Another specimen, showing same feature and connection of bases of fibers by periderm

Normanskill shale, Mt Moreno near Hudson, N. Y.

Lasiograptus bimucronatus Nicholson

See plate 29, figures 9–11; plate 31, figures 1–3

Page 481

6 Large macerated specimen retaining portions of the extrathecal periderm

7 Frontal aspect of rhabdosome, with few fibers

8 Specimen, retaining the triangular processes, their bounding fibers and cross fibers

Normanskill shale, Mt Moreno near Hudson, N. Y.

All figures are enlarged x 5. The original of figure 3 is in the American Museum of Natural History; the others are in the New York State Museum.

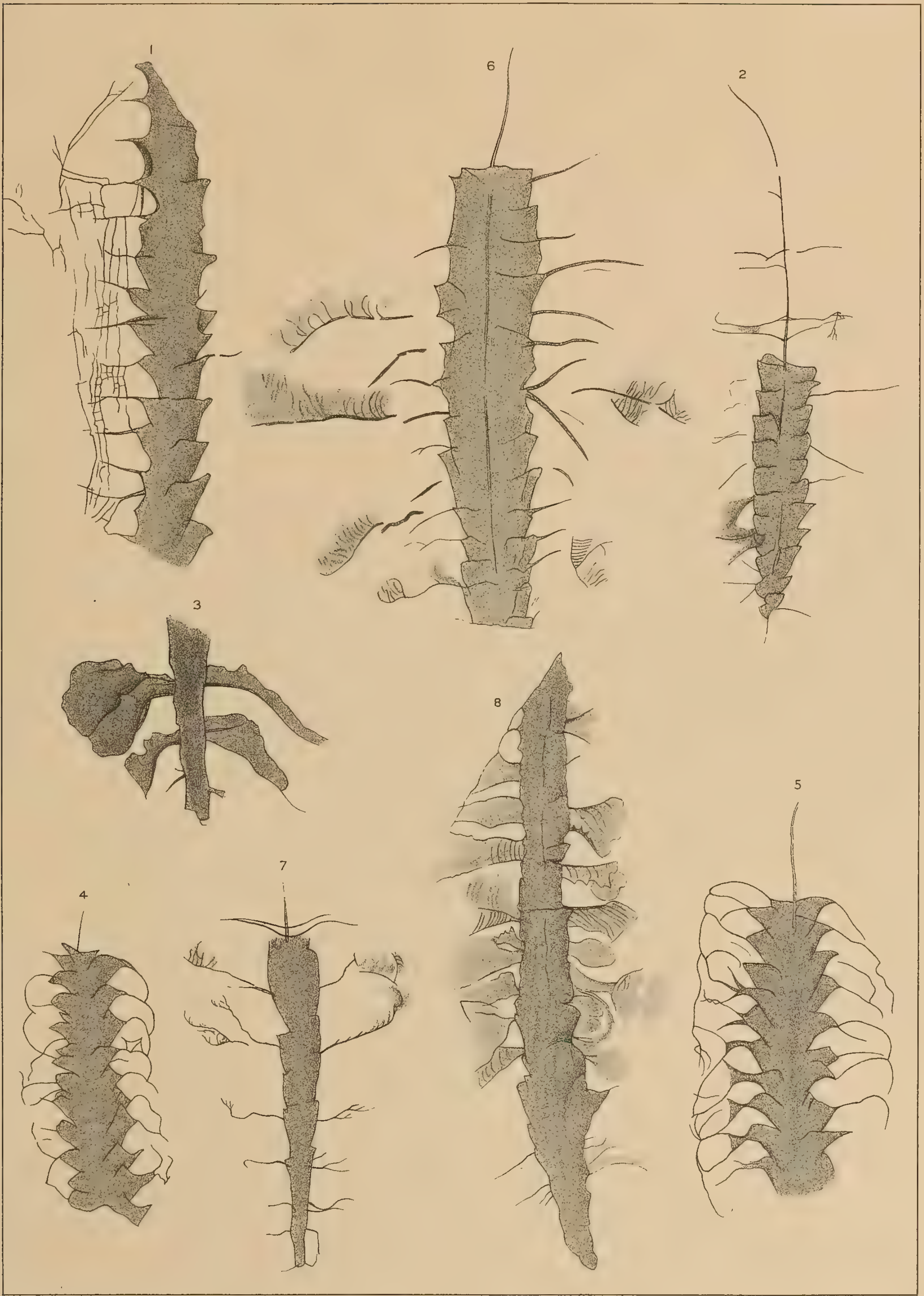

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PLATE 31

Genus LASIOGRAPTUS Nicholson

See plates 29, 30

Lasiograptus mucronatus (Hall)

See plate 29, figures 9–11; plate 30, figures 1–5

Page 479

1, 3 Proximal portions of synrhabdosomes [*see* pl. 29, fig. 9, 10]. In figure 1 the synrhabdosome has become entangled with the nemacaulus of a Climacograptus.

Normanskill shale, Glenmont, N. Y.

2 Enlargement of specimen to show the extrathecal structures

Normanskill shale, Mt Moreno near Hudson, N. Y.

Lasiograptus bimucronatus Nicholson

See plate 29, figures 12–18; plate 30, figures 6–8

Page 481

4 Young rhabdosome, showing sicula and fibers

Normanskill shale, Mt Moreno near Hudson, N. Y.

5 Diagram of rhabdosome of Lasiograptus

a Exterior aperture of extrathecal structure

b Aperture of theca

Retiolites geinitzianus Barrande var. **venosus** (Hall)

See plate 29, figures 7, 8

Page 469

6 Specimen showing the straight axis, the lateral ledges, portions of the reticulate layer and of the continuous periderm

7 Portion of rhabdosome showing the reticulate layer covering the axes on the lateral sides

8 Specimen in which both axes have become compressed into one plane

Clinton shale, Genesee gorge, Rochester, N. Y.

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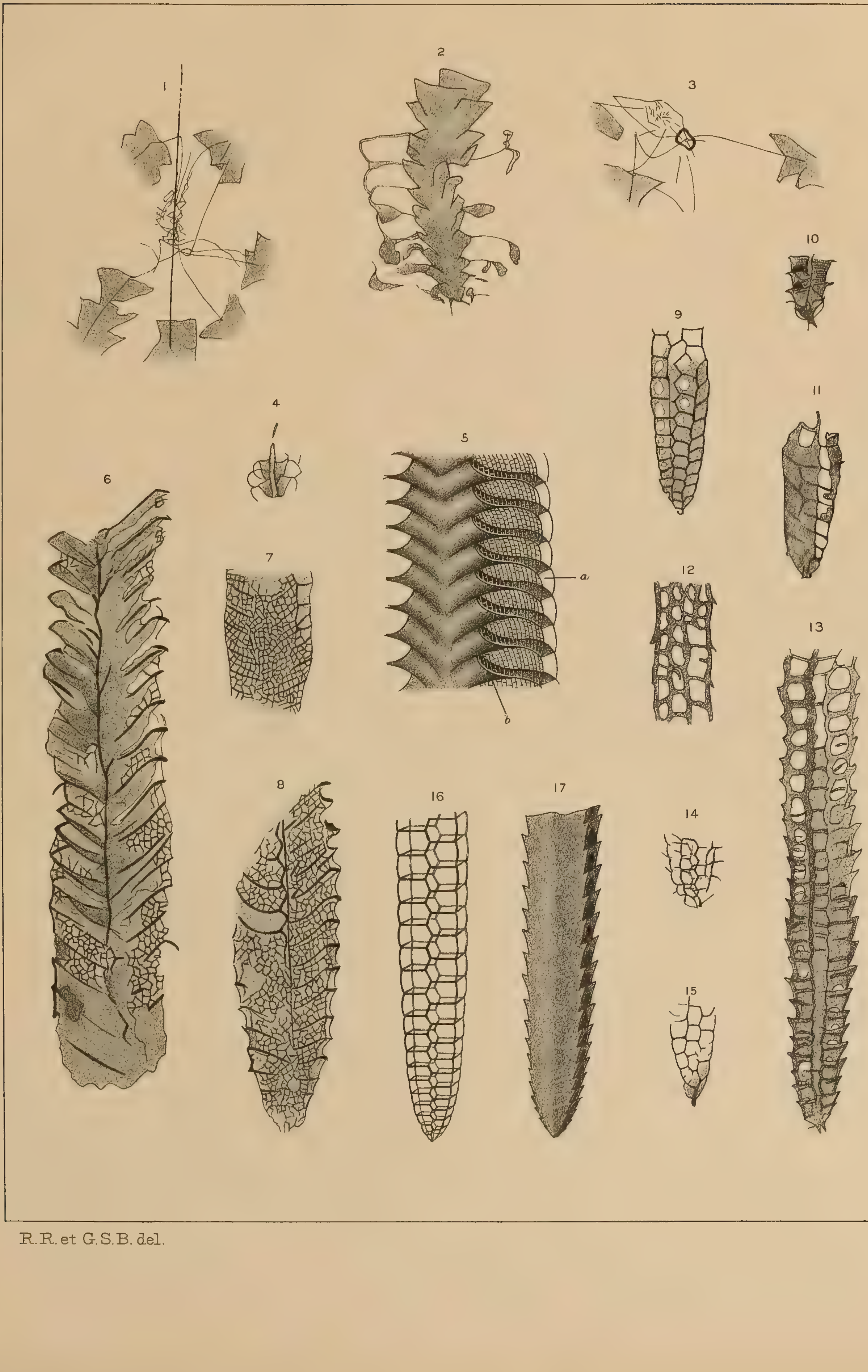
Plate 31



R. R. et G. S. B. del.

Genus RETIOGRAPTUS Hall

See plate 29

Retiograptus geinitzianus Hall

See plate 29, figures 5, 6

Page 463

9 Specimen exhibiting the ledges and continuous periderm. It is obliquely split so that both rows of apertural meshes are seen. x 4. Figure 11 represents opposite side of same fossil.

Normanskill shale, Chatham, N. Y.

10 Sicular end, showing sicula, form of thecae (on left side) and apertures. x 5

Normanskill shale, Schodack landing, N. Y.

11 Sicular end of rhabdosome, retaining the thick continuous periderm of the broad lateral face. x 4

Normanskill shale, Chatham, N. Y.

12 Portion of rhabdosome, showing the network of ledges with adhering wings of periderm. In the upper part four rows resulting from the preservation of fragments of both sides are seen. x 5

13 Compressed rhabdosome, showing the axes; the form of the apertural margins and the thinning out of the continuous periderm in anti-sicular direction. x 4½

Normanskill shale, Schodack landing, N. Y.

14 Sicular end of macerated specimen showing entire network of ledges. x 4

Normanskill shale, Kenwood near Albany, N. Y.

15 Sicular specimen showing the sicula. x 4

Normanskill shale, Schodack landing, N. Y.

16 Reconstruction of network of ledges, after the specimens here figured. Cross ledges connecting the zigzag axes probably existed, but are left out in the diagram as not positively seen.

17 Reconstruction of exterior view of rhabdosome, showing the flat or slightly sloping lateral faces, the apertural margins and the apertures.

All originals are in the New York State Museum.

INDEX

Page numbers referring to descriptions of fossils are printed in black face type.